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ARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES 1933

By ELMER HIGGINS

U.S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

PROGRESS IN BIOLOGICAL INQUIRIES
1933

By ELMER HIGGINS

APPENDIX III TO REPORT OF COMMISSIONER OF FISHERIES
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PROGRESS IN BIOLOGICAL INQUIRIES, 1933 [1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*

(With the collaboration of Investigators)

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INTRODUCTION

The work of the Division of Scientific Inquiry involves studies from a biological point of view of the various fisheries, in order to determine which are showing depletion and what methods may be applied toward their conservation as well as studies for the development of improved methods of cultivating aquatic animals. Research projects during the past year cover three major fields: (1) Marine and fresh-water commercial fishery investigations; (2) aquicultural investigations; and (3) shellfishery investigations. These projects are organized under seven distinct sections, each directed by a responsible and experienced fishery biologist, and are so distributed as to cover each of the major geographical sections of the United States. They include individual researches on more than 30 different species of commercially important food and game fish, shellfish, and crustaceans.

The various projects engaging the attention of the staff of 43 permanent employees were as follows:

Commercial fishery investigations:
  North and Middle Atlantic fishery investigations: Cod, haddock, mackerel, weakfish, scup, bluefish, and flounder.
  South Atlantic and Gulf fishery investigations: Shrimp and shore fishes.
  Great Lakes fishery investigations: Whitefish, cisco, herrings and chubs, pike perches, yellow perch.
  Pacific coast and Alaska fishery investigations: Red salmon, pink salmon, and herring.
Shellfishery investigations:
  Oyster cultural investigations in New England, South Atlantic, Gulf States, and Puget Sound.
Aquicultural investigations:
  Improvements in hatchery technique for feeding and breeding trout.
  Pond-fish cultural investigations for warm-water fishes.
  Treatment and cure of diseases of hatchery fish.
  California trout investigations.
  Studies in fish nutrition.
  Investigations in interior waters with respect to pollution and the propagation of pearl mussels.
  Stream surveys in the national parks and forests.

The scientific investigation of the fisheries, or of the fish on which the fisheries are based, provides data essential for the proper conservation of the resource. We must have information relative to such fundamental facts as the rate of growth, age at maturity, time and manner of spawning, habits of the young, feeding habits of both young and old, extent and direction of migrations, extent to which the various groups of fish mingle, particularly with respect to their interbreeding, and the enemies or other elements in their environment which tend to reduce the abundance of these fish and other forms in which we are mainly interested and from which we obtain our fishery products.

As a logical extension of these " life history studies " investigation relating to the growth and replacement of fish populations and their fluctuations in abundance are finding increasing application with respect to conservation and management of the great commercial fisheries, by yielding early evidence of depletion, should it occur, as a safeguard to expanding industry; and by predictions of future yields as a direct aid in the orderly conduct of the fishing business. The yield of the commercial fishery, and hence the success of a commercial enterprise, is dependent upon the three major variables: Birth rate, death rate, and migration. A " census " of the fish population upon which a fishery depends, revealing the rate of replacement of the stock, the occurrence of unusually successful spawning seasons, the withdrawals from the stock by normal death rate or by commercial fishing, together with additions or subtractions by the migration of the fish themselves, forms the basis for successful predictions of supplies available in future years. Hence, investigations of the commercial fishery are designed to produce evidence of this sort, which has great practical application in the protection as well as the wise use of our fishery resource.

As an aid to the work of artificial propagation of fish for restocking interior waters, studies are also conducted dealing with the pathology and nutrition of fishes and with improvements in hatchery technique and stocking practices. Moreover, aid to the water farmer in the cultivation of shellfish is rendered by the development of improved practices based upon a sound understanding of the natural requirements of the organisms cultivated.

In addition to these regular functions of the Division, various projects were authorized at the end of the year to be carried out as emergency work with funds from the Public Works Administration. These may be characterized as follows:

1. Stream surveys and stream improvement in the national parks and forests. Sixteen parties will spend periods ranging from 3 to 8 months in the field during 1934 in conducting physical and biological surveys of selected areas in the national parks and forests of the United States, distributed as follows: 4 in the Atlantic coast section, 9 in the Intermountain States, and 3 on the Pacific coast. The object of these surveys is primarily to determine a rational and effective policy of stocking these public waters with food and game fishes and, secondarily, to render such aid and advice as is possible in the areas under study to the United States Forest Service, for the purpose of so changing or improving natural conditions as to increase the carrying capacity of these streams and to facilitate natural reproduction of fishes.

2. A study of stream pollution in the Middle West, also financed by the Public Works Administration. A corps of biologists, biochemists, and engineers will be engaged for 1 year in studying the effects upon aquatic life, either direct or indirect, of industrial and trade wastes, domestic sewage, and river silt. Paralleling this investigation will be a further study by a part of the same staff of means of utilizing, in the increased production of fish food and food and game fishes, the nitrogenous wastes now destroyed but of considerable potential value and of isolating and neutralizing at their sources toxic or harmful wastes resulting from industrial processes now lead-

ing to serious pollution of our streams. This is a new attack by newly perfected methods upon the pollution problem from an entirely different angle than heretofore undertaken and if successful may make possible the adoption on a large scale of simplified methods of sewage treatment.

3. Construction of fish screens in the Pacific Northwest by Public Works funds to prevent the destruction of downstream migrating salmon and other food fishes by irrigation works on Government properties such as reclamation projects or Indian reservations.

4. Investigation of the requirements for fish-protective works at the various hydroelectric, irrigation, and navigation dams on the Columbia River. This project has been financed by the Public Works Administration for a study of fishways and other protective works at the Bonneville (Oreg.) Dam and should be extended to the Rock Island and Grand Coulee Dams.

Much of this work will not actually be undertaken until the spring and summer of 1934. Hence, reports of these activities will be presented in the next annual report of this Division.

STATE COOPERATION

The biological investigations of the Bureau, forming as they do the very foundation of the conservation efforts of the States, have always received liberal support and in many cases active cooperation from the State fish and game departments. The Bureau's investigations, conducted on the highest scientific plane, are always regarded as disinterested and authoritative, and, hence, exert a very real influence on the trend of thought in conservation circles and on local legislation.

Because of the tremendous field to be covered and the relative inadequacy of financial support, the projects for scientific investigation are necessarily chosen because of their wide and general applicability in the protection and development of the fishery resources, and hence local problems frequently remain unsolved for many years. For example, attention is first given to those great commercial fisheries of importance over wide areas for the purpose of determining their trend and present condition either as a guide to their regulation or as a guide to industry in the better utilization of the annual harvests and in avoiding disastrous gluts or famines in the market.

In determining the changes in relative abundance from year to year of the total supply of species supporting a great fishery, problems of local management arise, which, under the circumstances, must be neglected by the Federal Government and must remain unsolved unless the State Governments are able and willing to cooperate in determining the conditions that affect their local fishery. On the Atlantic coast of the United States, for example, the abundance of fish in any of the bays or channels of Long Island or New Jersey, or even in Chesapeake Bay, are largely determined by the variations in abundance in the main stock of fish in the offshore waters. The Bureau's investigations have shown that the weakfish, the scup, the flounder, and the bluefish all migrate extensively over the area from the Carolinas to Cape Cod, and that the spawning areas for most of these species lie chiefly in southern waters. Hence, the regulation of fishing in a Long Island bay would have little effect upon the total fish supply, and whether or not net fishing is regulated or prohibited is entirely a matter of local policy of an economic rather than a biological nature. It remains for the State cooperating biologists to determine by appropriate studies the degree of interchange between local and more generally distributed populations of fish, and the effects of fishing different types of gear upon the local supply.

For many years most gratifying cooperation has been received by the Bureau's biologists from the States. California is now engaged in a cooperative investigation of the trout supplies in California, looking toward a more adequate restocking of the streams and a more rational regulation of fishing. New York State is cooperating in the conduct of a study of the nutritional requirements of trout to improve hatchery practices in feeding and rearing. Oregon has arranged to cooperate with a Bureau investigator in a study of fish diseases in hatcheries. Mississippi has during the past year assisted materially in a survey of their fishing waters. Michigan and Wisconsin have cooperated in the study of the great commercial fisheries in Lakes Michigan and Huron, and an extensive cooperative project has recently been completed in Lake Erie in which Ohio and New York were the chief collaborators with the Bureau. North Carolina, Connecticut, Washington, and Louisiana are assisting in investigations looking to the restoration of the oyster beds of their coastal waters, and similar cooperation has been afforded by Florida and Texas in the past. Georgia, Louisiana, and Texas have joined hands with the Bureau in an extensive study of the great shrimp fishery of the South Atlantic and Gulf coasts. Such cooperation should be materially extended for most fish are migratory; few are limited to strictly State waters; many are international.

While cooperation has been most extensive in a study of the marine fishes, a fertile field for further cooperation remains in the inland waters. Especially are the pollution problems interstate in character for the effects of industrial wastes from mining and manufacturing frequently extend down stream through several State jurisdictions. This is a field in which the Bureau has heretofore taken but a minor part, but owing to recent legislation the Bureau is authorized to undertake such studies, and a material extension of this type of work, which can be made most effective with wholehearted State cooperation, is anticipated.

PUBLICATIONS

Owing to the curtailed funds for printing the number of publications resulting from investigations of the staff or conducted under the supervision of the Division has been reduced. The list of papers published by the Bureau during 1933 follows:

Higgins, Elmer.
    Progress in biological inquiries, 1932. Appendix 2, Report, Commissioner of Fisheries, 1933, pp. 79–147.
Sette, O. E.
    Outlook for mackerel fishery in 1933. Fishery Circular No. 14, 23 pp., 7 figs.

RICH, WILLIS H., and EDWARD M. BALL.
Statistical review of Alaska salmon fisheries. Pt. 4—Southeastern Alaska. Bulletin, vol. 47, pp. 437–673, 55 figs. Bulletin No. 13.
WEYMOUTH, F. W., MILTON J. LINDNER, and W. W. ANDERSON.
Preliminary reports on the life history of the common shrimp, *Penaeus setiferus* (Linn.). Bulletin, vol. 48, pp. 1–26, 11 figs. Bulletin No. 14.

The following papers were published by members of the staff of the Division of Scientific Inquiry or cooperating investigators during the year 1933 outside of the Bureau of Fisheries' series:

BIGELOW, H. B.
Studies of the waters on the continental shelf, Cape Cod to Chesapeake Bay. I. The cycle of temperature. Papers in physical oceanography and meteorology. Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, vol. 2, no. 4, 135 pp., 66 figs., December.
CHAMBERLAIN, T. K.
Ages and shell measurement of two large specimens of *Megalonaias gigantea* (Barnes). The Nautilus, vol. 67, p. 29, July.
DAVIDSON, FREDERICK A.
Temporary high carbon dioxide content in an Alaska stream at sunset. Ecology, vol. 19, no. 2, pp. 238–240.
Homing instinct and age at maturity of the pink salmon. Pacific Fisherman, vol. 31, no. 8, p. 13, July.
U.S. Bureau of Fisheries conducts inquiry life history of pink salmon. The Wrangell Sentinel, July 14.
DAVIS, H. S.
Recent advances in our knowledge of epidemic diseases among fish in the countries bordering on the Pacific. Proceedings, Fifth Pacific Science Congress.
DEASON, HILARY J.
Geological formation of Great Lakes. The Fisherman, vol. 2, no. 3, pp. 3–4, 10, February.
Feeding adaptations in fishes. The Fisherman, vol. 2, no. 7, pp. 3–4, 10–11, July.
DUDEN, WILLIAM R.
Recent advances in the fishing industry. The Fisherman, pt. I, vol. 2, no. 10, pp. 3–4, 10–11, October.
Recent advances in the fishing industry. The Fisherman, pt. II, vol. 2, no. 12, pp. 3–4, 10, November.
ELLIS, M. M., and D. B. CALVIN.
Glycogen storage by fresh water mussels. American Journal of Physiology, vol. 101, p. 32
FISH, FREDERICK F.
The chemical disinfection of trout ponds. Transactions, American Fisheries Society, vol. 63.
FIRTH, FRANK E.
Concerning three-eyed fishes. The Scientific Monthly, vol. 26, pp. 472–473.
An occurrence of a tunicate killing a fish. Bulletin, Boston Society of Natural History, no. 69, pp. 3–5.
GALTSOFF, P. S.
Pearl and Hermes Reef, Hawaii, hydrographical and biological observations. Bernice P. Bishop Museum Bulletin 107, 5 pl., 3 charts, 49 pp. Honolulu.
GALTSOFF, P. S., and L. E. CABLE.
The current rotor. Science, vol. 77, no. 1992, p. 242.
GINSBURG, ISAAC.
Descriptions of new and imperfectly known species and genera of gobioid and pleuronectid fishes in the U.S. National Museum. Proceedings, U.S. National Museum, vol. 82, art. 20, 23 pp., 3 figs.
A revision of the genus Gobiosoma (Family *Gobiidae*) with an account of the genus *Garmannia*. Bulletin, Bingham Oceanographic Collection, vol. 4, art. 5, 59 pp., 3 figs.
Descriptions of five new species of seahorses. Journal, Washington Academy of Science, vol. 23, pp. 560–563.

HAZZARD, ALBERT S.
Fish planting investigations. Utah Agricultural Experiment Station. Miscellaneous Publication No. 10.
Fisheries research in the Uinta Mountain region. Outdoor America, February–March.
Some phases of the life history of the eastern brook trout, *Salvelinus fontinalis* Mitchell. Transactions, American Fisheries Society, vol. 62, pp. 344–350, 11 figs.
The dry fly. The Rocky Mountain Sportsman, August.
Trout flies and trout foods. The Rocky Mountain Sportsman, September.
Game fish of the Rockies. The Rocky Mountain Sportsman, November.

HERRINGTON, WM. C.
Savings gear and the fisheries code. Fishing, vol. 13, no. 7, pp. 15–16.

HERRINGTON, WM. C., and J. R. WEBSTER.
Why there are good and bad haddock years. Fishing Gazette, vol. 50, no. 10, pp. 4–6, 23.

HIGGINS, ELMER.
Lobster conservation demands protection for the big egg producers. Fishing, vol. 12, no. 1, pp. 18–20, 40–41.

HILDEBRAND, SAMUEL F.
Hybridizing diamond-back terrapins. Journal of Heredity, vol. 24, no. 6, June.

HOLMES, HARLAN B.
Importance of biological study to the Alaska red salmon fishery. Pacific Fisherman, vol. 31, no. 1, pp. 23–24, January.

JUDAY, CHANCEY, and E. A. BIRGE.
The transparency, the color, and the specific conductance of the lake waters of northeastern Wisconsin. Transactions, Wisconsin Academy of Sciences, Arts, and Letters, vol. 28, pp. 205–259.

JUDAY, CHANCEY, and E. SCHNEBERGER.
Growth studies of game fish in Wisconsin waters. Second Report, April.

KOEHRING, V., and H. F. PRYTHERCH.
Shellfish opened by new method. Western Fisheries, vol. 6, no. 3, pp. 5–8, July.

LINDNER, MILTON J.
Progress in shrimp investigations during the year 1932. Louisiana Conservation Review, vol. 3, no. 2, pp. 50–53, 4 figs., April.

LOCKE, S. B., and ALBERT S. HAZZARD.
Utah—resources and activities. Chapter 9, animal life-fish. Department of Public Instruction, pp. 115–147.

LOOSANOFF, V. L.
Observations on propagation of oysters in James and Corrotoman Rivers and Seaside of Virginia. 4 pl., 46 pp. The Virginia Commission of Fisheries, Newport News, Va.

LORD, RUSSELL F.
What about those hatchery trout? Field and Stream, December.
Types of food taken throughout the year by brook trout. Transactions, American Fisheries Society, vol. 63.

MCCAY, C. M.
A continuous extractor of large capacity. Journal, Industrial and Engineering Chemistry, vol. 5, p. 213.

MEEHEAN, O. LLOYD.
The role of fertilizers in pond production. Transactions, American Fisheries Society, vol. 63.

MOTLEY, H. L.
Histology of the fresh water mussel heart, with reference to its physiological reactions. Journal of Morphology, no. 2, vol. 54, p. 415.

NEEDHAM, P. R.
The California trout investigations. California Fish and Game magazine, vol. 19, no. 2, April.
Notes on the use of water fleas as fish food. Transactions, American Fisheries Society, vol. 63.

NESBIT, R. A.
Do northern weaks come from the South? Fishing, vol. 13, no. 4, p. 8.

Neville, Wm. C.
Temperature and the southern trawler. Fishing, vol. 12, no. 12, pp. 4–5.
Will the winter fishery off Virginia ruin the industry? Fishing Gazette, vol. 50, no. 6, pp. 10–11, 16.

Parr, A. E.
A geographic-ecological analysis of the seasonal changes in temperature conditions in shallow water along the Atlantic coast of the United States. Bulletin, Bingham Oceanographic Collection, vol. 4, art. 3, 90 pp., 28 figs., January.

Pearson, John C.
Movements of striped bass in Chesapeake Bay. Maryland Fisheries, pp. 15–17, May.
Unique fishery for the striped bass or rockfish in Massachusetts. Maryland Fisheries, pp. 16–18, September.

Prytherch, Herbert F.
The oyster industry has progressed from steadily pursued research and experiment. Fishing Gazette, Annual Review Number, vol. 50, no. 7, pp. 42–45, June.

Rounsefell, George A., and Edwin H. Dahlgren.
Tagging experiments on the Pacific herring (*Clupea pallasii*). Journal du Conseil, vol. 8, no. 3, pp. 371–384, December.

Surber, E. W.
A quantitative study of rainbow trout production in one mile of stream. Transactions, American Fisheries Society, vol. 63.
Observations on circular pool management. Transactions, American Fisheries Society, vol. 63.

Taft, Alan C.
Methods for counting small fish in hatcheries. California Fish and Game magazine, vol. 19, no. 2, pp. 122–126.
California steelhead trout problems. California Fish and Game magazine, vol. 19, no. 3, pp. 192–199.

Weymouth, F. W., Milton J. Lindner, and W. W. Anderson.
A summary of the life history of the common shrimp, *Penaeus setiferus*, of the South Atlantic and Gulf coasts of the United States. Transactions, American Fisheries Society, vol. 62, pp. 108–110.

Wiebe, A. H.
The effect of high concentrations of dissolved oxygen on several species of pond fish. Ohio Journal of Science, vol. 33, no. 2.
The ability of fresh-water fish to extract oxygen at different hydrogen-ion concentrations. Physiological Zoology.
The oxygen consumption of the black bass (*Huro floridana* LeSueur). Transactions, American Fisheries Society, vol. 63 .

Van Oosten, John.
Preliminary report on investigation of chub net meshes in Lake Michigan. The Fisherman, vol. 2, no. 4, pp. 3–4, 8, March.

The following progress reports covering the more important investigations of the Division during the calendar year 1933 were prepared in the main by investigators in charge of the various projects.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

In common with other activities of the Division, the work in this region has been curtailed severely by reduction in available funds, which has necessitated the withdrawal from service of the fisheries research steamer *Albatross II*, and loss from the staff of a junior biologist and two biological aides. This has interrupted to a serious degree much of the field work which furnishes the basis for an appraisal of the conditions of the fisheries and has necessitated discontinuation of the work on cod, flounders, and butterfish, though results of taggings of the first two named continue to be received. Lack of personnel to assist in the analysis of data has also retarded achievement of results. That our insight into the needs of the fisheries should become clouded at this time is particularly unfortunate for the organization of the fishing industries now in process could be much more effective in providing orderly conduct of the business if information as to the probable future abundance of commercial species were available. Furthermore, the present situation offers unprecedented opportunities for securing sane utilization of the fishery resources and for assuring their continued productivity, if the biological basis for planned utilization could keep pace with the industrial developments.

As now constituted, work in this region has been limited to the investigations on the haddock, mackerel, and certain of the shore fishes of the Middle Atlantic States, notably the squeteague or sea trout and the scup. Thanks to tagging in former years, some additional results may be reported on the cod and on the winter flounder, *Pseudopleuronectes americanus.*

As in former years, the staff, under the direction of O. E. Sette, has been provided with laboratory and library facilities by the Harvard Biological Laboratories and the Museum of Comparative Zoology at Harvard University, Cambridge, Mass., where its members have also benefited from consultation with members of the university, especially Henry B. Bigelow, professor of oceanography and director of the Woods Hole Oceanographic Institution, whose wealth of knowledge and experience relating to marine fisheries research has been ever at the disposal of the Bureau employees. It is a pleasure also to acknowledge the continued cooperation of fishermen and fishing companies in providing data essential to the progress of the work.

HADDOCK

During 1933 the investigation of the haddock fishery has been concentrated on the important year-to-year changes in abundance. The work has continued under the direction of W. C. Herrington while the catch record analysis has been handled by J. R. Webster and the collection of data on the Boston Fish Pier by F. L. Widerstrom during the first part of the year and by F. E. Firth during the latter part. Progress both in the field and in the laboratory was handicapped by injuries to two assistants—A. A. Dallas was injured in January while at sea on the otter trawler *Cormorant* and was incapacitated during the remainder of the year, while G. Sinnett, a temporary employee, broke his leg during a tagging trip in June on the line trawler *Mary E. O'Hara.* During the last half of 1933 the work was considerably curtailed by loss of personnél and reduced budget. The present program is confined mainly to a study of changes in abundance and their causes, through analysis of catch records and length-frequency data obtained principally at the Boston Fish Pier where most of the haddock catch is landed.

Results already have provided a good understanding of the causes of the fluctuations and indicate what measures give most promise for counteracting the declining trend of abundance that is becoming evident. This decline, to be discussed below, apparently is the result of the greatly increased fishing strain imposed by the growth of the haddock fleet during the period of 1925–29. Increases and decreases in the average abundance arise from causes which now appear quite clear cut and comprehensible. An increase follows one or a series of good spawning seasons while a series of poor spawning years results in a rapid drop in the catch. Changes in abundance from bank to bank and within the year principally are the results of mass movements of the fish and appear to follow a fairly regular seasonal cycle. There also is a regular decrease in the catch from summer to winter and an increase from winter to summer which may be the result of seasonal changes in the schooling habits of the fish.

Georges Bank fishery (*including South Channel and Nantucket Shoals*).—Our data show that the rapid increase in haddock landings, from about 85,000,000 pounds in 1923 to more than 250,000,000 pounds in 1929, was due in part to an increase in the otter trawl fleet and in part to a great increase in abundance of fish on Georges Bank which during these years accounted for about 80 percent of the haddock landed in the United States. This high level of abundance was the result of a series of exceptionally successful spawning seasons during the years 1920–24.

The increase in abundance came to an abrupt halt in 1928 as the result of a series of very poor spawning years, 1925–28, which added relatively few young fish to the population. The commercial stock on Georges Bank, lacking appreciable additions of upgrowing young fish from these poor years, in 1928 began to decrease rapidly under the heavy inroads of fishery. However, the total haddock landings continued to rise until 1929 owing to the addition of new boats to the fleet and to the increased proportion of time spent at sea by all trawlers. The rapid decline begun in 1928 continued until 1930 and 1931 when the level of abundance was the lowest in the history of the fishery. In spite of a gradual shift to the use of the new V–D gear the large otter trawlers were averaging but 5,000 to 6,000 pounds of haddock a day compared to the 18,000 to 20,000 pounds averaged in 1926 and 1927 with the less effective type of trawls then in use.

This rapid downward trend in abundance on Georges Bank was finally halted by the young haddock from the successful spawning year of 1929 which reached commercial size in the winter and spring of 1932. As a result of this influx of young haddock the scrod catch in 1932 averaged nearly three times as great as in the previous year while the average catch per trawler day of all haddock was approximately 40 percent more than in 1931.

By the time the 1933 season was well under way the trend in the catch once more turned downward. The 1929 class had attained its maximum effect in 1932 and had begun to decline in the face of a still intensive fishery, and as the 1930 spawning had been a relative failure there were few additions of upgrowing young fish to replace those caught off by the hundreds of line trawlers and otter trawlers hard at work on the banks. Consequently, the average catch per trawler day for 1933 was nearly 20 percent lower than in 1932.

The fishery on Georges Bank appears to be due for a continued decline for the next 2 years unless, as is remotely possible, there develops a considerable immigration of haddock from the eastern banks

(Browns, Sable Island, etc.). The 1931 class, which came into the fishery in the late fall of 1933, to some extent will augment the catch in 1934 but its effect cannot be determined at present owing to our inability to collect sufficient data at sea during the past year. However, a very rough approximation of the relative abundance of this year class, obtained from the limited data collected on trawler trips in 1932 and from commercial catch data for November and December 1933 is that the 1931 class is somewhat less than half as abundant as was the 1929 class at the same age. If this be the case, this group may be sufficiently large to maintain the commercial haddock population on Georges Bank at about the same level as in 1933, providing that the majority of the large otter trawlers continue to do most of their fishing on the eastern banks rather than on Georges. It appears more probable, however, that the catch per trawler day in 1934 will be less than in 1933.

The catch in 1935 depends on the degree of success of the 1932 spawning season. Fish of this year class would have averaged somewhat less than 35 centimeters in length during 1933 and if abundant would have been taken in large numbers by the commercial trawlers. No reports of such catches have been received during the past year; consequently, it appears that the 1932 class was a relative failure. Haddock of this year group can provide the only additions to the fishery in 1935; if it was a failure as the above evidence indicates, the level of abundance in 1935 must again show a marked decline.

Eastern banks fishery.—Under eastern banks we have grouped all the haddock grounds east of the Fundian Channel (the deep gully separating Georges from Browns Bank). From present data this gully appears to form a complete barrier to the movements of the young haddock during the entire year and to the older fish during most of the year. For example, the 1929 year class showed no movements across the channel until their fourth winter (that of 1932–33) and the older fish have shown mass movements across this channel only around the spawning season. The details of these movements have not yet been worked out.

The chief distinguishing characteristic of the haddock populations of the regions east and west of the Fundian Channel is the difference in the rate of growth of the younger fish. For example, on Georges Bank the 1929 class reached commercial size during the winter of 1931–32 and spring of 1932, while on the eastern banks the same year class did not reach commercial size until the spring and summer of 1933, a difference of about a year and a half. The same difference is being indicated by the 1931 year class. A difference in growth rate probably continues in the older fish but is less evident because of increasing intermixture of the stocks.

As a result of growth differences the 1929 class did not have its full effect on the eastern banks fishery until the summer of 1933. Only a few boats were fishing the area at that time but shortly afterward most of the large otter trawlers shifted their activities from Georges to the eastern banks in the vicinity of Sable Island, where extremely good catches of scrod haddock were being taken. These large scrod catches brought the average catch per trawler day for 1933 up to a level approximately 40 percent higher than for 1932.

Because of the recent influx of the 1929 year class into the commercial catch the prospects for the eastern banks fishery in the next 2 years are better than for the fishery on Georges. In the spring and summer of 1934 the upgrowth of young haddock of the 1929 class should cause a very considerable increase in the average catch per day of scrod haddock. The late fall fishery should show an increase over 1933 in the catch of large haddock but a decrease in scrod. The level of abundance for the entire year should be considerably higher than in 1933, depending on how well this stock of fish can survive the present intensive fishery. By 1935 these banks should begin to show a decline similar to that on Georges in 1933.

Summary for all banks.—The difference in growth rate on Georges Bank and the eastern areas acts as a very efficient means of spreading over a period of 2 to 3 years the maximum effect of an abundant year class instead of concentrating it in one fishing season. Except for this phenomenon the effects of good and poor year classes would be much more drastic than has been the case. Under these conditions, with a fleet that can operate either on Georges or on the eastern banks, the fishery as a whole can maintain a fairly even level if a good spawning season, such as that in 1929, occurs every 3 years. If good spawning seasons occur at intervals of less than 3 years, the level of the fishery should rise, while if the intervals are more than 3 years, the level should fall.

A summary may now be given of the past and expected future course of the fishery as affected by the spawning seasons 1929–32 of which the 1929 season was very successful, the 1930 season a failure, the 1931 season poor, and the 1932 season appears to have been a failure. Resulting from the haddock spawned in these years there was a distinct improvement in the fishery in 1932 (1929 class on Georges) and maintenance of the catch in 1933 (1929 class on eastern banks). In 1934 the fishery as a whole may be expected to maintain a level near that of 1933, possibly somewhat better (1929 class on eastern banks and 1931 class on Georges) while in 1935 there should be a distinct decline in the catch per trawler day (3 spawning years either failure or poor, 1930–32). Developments in 1936 will depend on whether the 1933 spawning season was a success, fair, or a failure.

A long-range view of the haddock fishery (1916–35) suggests that in the last 10 years there has been a decided decline in the level of abundance of the haddock population. The catch per trawler day during the past 4 years (1930–33) has been but about 52 percent as much as the average for 1916–30 in spite of improvements in the nets and other gear. Taken by 5-year periods the averages per trawler day were 1916–20, 14,600; 1921–25, 13,400; 1926–30, 14,800; 1931–33, 8,100. Even assuming a 25 percent improvement in the catch for 1934 and a level in 1935 equal to 1933, the average for 1931–35 will be little more than half as much as for the previous 15 years.

Present haddock program.—To maintain our present qualitative analysis of the condition of the fishery and its expected future trend, we must continue the catch record and length-frequency analysis which has been under way since 1931. In addition, more data on small haddock will have to be obtained at sea from trawler trips. However, if estimates of future abundance are to be more precise and if measures for counteracting the declining trend of the fishery are to be developed, it is essential that certain additional work be undertaken. This includes a systematic collection at sea of data on the size and abundance of young haddock below commercial size and the study of growth and migrations through analysis of scale data and through tagging experiments.

Among these requirements the one farthest from realization is the collection of adequate data on the size and abundance of the young haddock below commercial size. Although some data of this type can be obtained by investigators making regular trips on commercial trawlers, satisfactory data cannot be collected without the use of an able research vessel equipped for trawling.

The study of growth and migrations through analysis of scales and by tagging experiments has suffered through lack of time rather than lack of material. Some age and growth determinations have been made from the scales to verify the interpretation of our length-frequency data, but we have not been able to give this subject the attention it deserves. Experiments with captive haddock have developed a tag which gave good results from releases along the Maine coast, but so far neither this nor other types of tags tried on haddock caught by commercial fishermen on the offshore banks has given even encouraging results. Since it appears probable that these failures may be caused by the rough treatment necessarily suffered by haddock when taken in commercial gear, it may be necessary to await the time that a research vessel is available to permit the careful handling necessary for tagging operations.

Savings gear.—It is apparent that in recent years there has been a decided downward trend in the haddock population level and that under the present fishery this trend can be expected to continue unless remedial measures are adopted. The single most unequivocally practical and beneficial measure now apparent is the prevention of the capture of haddock below market size. These haddock, if left in the ocean, later with increasing size would help to maintain the commercial catch at a higher level than would be possible otherwise. The means by which a large part of this saving may be accomplished has been demonstrated by the Bureau's work on "savings gear" in 1931 and 1932. At present several of the boat operators are trying out the recommended modifications in the construction of otter trawls. The scarcity of undersized haddock during the past year and distractions of the economic situation have prevented the problem from receiving the attention it deserves. Recommendations have been made to the N.R.A. code authorities for including the restriction of mesh size in the fishery code.

Early life history.—The 1932 observations on early life history were limited to one June cruise covering the area from Nantucket Shoals to Cape Sable, Nova Scotia. The trip was made possible by the kindness of the Woods Hole Oceanographic Institution in detailing for our use the *Atlantis* with her equipment and crew. Although the cruise was made later in the season than those of the 2 previous years, it provided valuable information on the distribution of the late larval stages of the haddock and added another valuable hydrographic survey to our series of records. Probably of most interest are the returns from drift-bottle releases during 3 successive years, 1931–33, in the Georges Bank-South Channel region.

The returns from 1931 and 1933 are similar in that most of the returned cards were from the shores of New England and the Bay of Fundy. In contrast, almost half of the returns from 1932 releases were from across the Atlantic. Hence it appears that in 1931 and 1933 the surface currents were resultantly westward and northward. In 1932, on the other hand, the drift was strongly to the southward off the banks and thence to the eastward.

These differences are significant because of their bearing upon the destinations of fish eggs spawned in the affected areas. Their continued study may throw much light on the causes for the success or failure of the spawning seasons.

We have been able to continue during the past year the arrangements, with L. A. Walford of the Harvard Graduate School, for the analysis of the collections of eggs and larvae. The results continue to indicate that there is little or no transfer of haddock eggs or larvae from Georges to Browns Bank or the reverse.

MACKEREL

A statistical review of the American mackerel fishery, which was completed during the past year, is eloquent of the sharp fluctuations in yield that have characterized this important fishery throughout its history. The investigations here reported upon have been designed to ascertain the causes of these remarkable fluctuations and to devise such means as may be practicable to counteract their ill effects.

It has been found that the changes in abundance responsible for the fluctuations in yield are caused mainly by the unequal numbers of young mackerel added to the stock annually as a result of reproduction. For instance, the additions of young were remarkably large in 1923, 1930, and 1931; they were only moderate in 1921, 1928, and 1929; and were few or none, in all other years. As a result of the remarkable production of young in 1923, the first of the "good years" observed, the catch rose to a peak in 1926. However, with the failure of the ensuing years the catch again declined until the 1928 class of young caused a recovery in 1929. Following this increase there followed another decline which persisted until the highly successful reproductions of 1930 and 1931 increased the commercial stock to a level which in 1932 and 1933 was comparable with that of 1926.

Almost as remarkable as the inequalities in reproductive success from year to year are the differences between year classes in their relative rates of decline and geographical distribution during the years following their first appearance in the fishery. Two general types are distinguishable: a "persistent type" that affords a moderate yield in its second year, a maximum yield in the following year, and thereafter declines moderately, the decline being so gradual that contributions to the commercial catch remain important for a decade or more; and a "transitory type" that furnishes its maximum yield in its second year and thereafter declines so sharply that its effect is felt in the commercial fishery for only 2 or 3 years. The persistent type is further distinguished by its continued presence throughout almost the entire fishing season in waters south of Nova Scotia but never extending to Nova Scotian waters. The transitory type, on the other hand, appears in the United States fishery mainly in the spring and late fall and also usually extends along the coast of Nova Scotia and even into the Gulf of St. Lawrence.

Obviously, knowledge of the relative abundance of various year classes together with their respective rate of decline acording to type affords a basis for predicting future abundance of mackerel. This in turn should permit the industry to plan its activities in advance, thus ameliorating the otherwise disorganizing effects of unexpected gluts and famines of supply.

The knowledge essential for predictions is based on a measure of relative abundance secured from an analysis of the catch per mackerel vessel coupled with a study of the ages of the mackerel present in the stock as judged from samples of the catches landed by commercial fishermen. In 1933, as during former years, this work was under the direction of O. E. Sette, assisted by F. E. Firth, who made the necessary observations on the mackerel catch at Cape May, N.J., during April; at New York during May; at Boston from June to October; and at Gloucester during November and December. Of the 2,651 fares landed during 1933, aggregating 29,528,100 pounds, 1,612 were recorded by localities of capture through interviews with captains and 881 were sampled to provide information on the ages of mackerel, in the course of which 26,094 individuals were measured and 1,733 scale samples were collected and subsequently examined to determine the age of the fish from which they were taken.

The 1933 season interposed unusual difficulties to biological study because, by voluntary agreement among the vessel owners and operators, the activities of the fleet during most of the season were restricted greatly both as to the periods of time each vessel was permitted to operate and as to the maximum fare which each vessel could land. These important modifications in the operations of the fleet required the employment of special methods to determine the abundance in 1933 relative to that of former years. However, by applying appropriate corrections it appears that the abundance of mackerel in 1933 was at least 22 percent greater than in 1932, and that if the fleet had operated without restrictions the catch would have been at least 55,000,000 pounds as compared with the actual catch under the restrictions in force of 29,528,100 pounds. The first-named quantity is within 2,000,000 pounds or 4 percent of the " high estimate " given in our prediction for the season and within 11,000,000 pounds or 25 percent of the " most probable estimate."

Biologically, conditions in 1933 were of particular interest, for the events of this year were critical in determining whether or not the class of 1931 was of the persistent type. Prior to the opening of the season it already had been concluded that the 1930 class was of the persistent type, but there was considerable doubt as to the type of the 1931 class. In predicting, the " most probable estimate " was based on the assumption that it was of the transitory type merely because the latter had occurred somewhat more often than the former. Recognition that the 1931 class might be of the persistent type formed the basis for the " high estimate." Inasmuch as the latter would have been realized if fishing had been unrestricted, there is afforded convincing evidence that the 1931 class is of the persistent type.

With two important year classes present in the stock of mackerel, both of them of the persistent type, which may be expected to suffer only a gradual, moderate decline during the next decade, and since these now dominate the catch, it appears that relatively high, though gradually declining, abundance is assured during a number of years even though no important new year classes appear in the immediate future. Of course, the advent of such year classes would raise the level of abundance still higher, perhaps halting the decline and possibly causing heights of abundance exceeding any that have been observed since the present studies were initiated.

The results of predictions during the past 6 years have demonstrated not only the practicability of the method but also have indicated two primary weaknesses which must be eliminated if the system is to attain the accuracy that is essential in the event that commercial operations are to be adjusted to the prospective yield. These are: First, lack of means to estimate the prospective abundance of yearlings; and, second, inability to determine the type of year class prior to its second year in the commercial fishery. We believe that both of these difficulties may be overcome by appropriate investigation of the biological factors involved. To solve the first-named question, the services of a suitably equipped research vessel are necessary to survey the relative abundance of mackerel that are too young to form a part of the commercial catch. The second probably would yield to suitably designed, large-scale tagging experiments coupled with morphometric analyses of the differences between year classes. The personnel and equipment at present available are inadequate to undertake these phases of the work.

A further question demanding early attention involves the merits of the present practice of catching large quantities of yearling mackerel. These mackerel are so small that disproportionately large numbers of individuals must be caught to make up a moderate poundage, and at the same time their worth in the market per pound is usually only a fraction of that of fish only 1 year older. A solution involves a study of the losses through mortality and decreased availability compared with the gains due to increased weight per individual and increased price per pound. Here again much light might result from tagging experiments.

With tagging looming as an important future technique, experiments were undertaken during 1933 to determine suitable methods of marking this delicate species. The results demonstrate the feasibility of securing quantitative results from tagging methods but at the same time they indicate extraordinary difficulties which can be overcome only by special procedure that involves either the services of a research vessel or a chartered mackerel-fishing vessel.

COD

The continued interest of W. C. Schroeder, formerly of the Bureau of Fisheries but now with the Woods Hole Oceanographic Institution, in the migration of cod has made it possible to analyze the returns from tagged cod released in 1932 and former years, though limitation of funds prevented the initiation of any new experiments. The releases of 1931 and 1932 are of most interest, for they were designed to provide information as to whether or not the small cod that predominate on the grounds along the coast of Maine gradually spread to offshore grounds as they grow older and in this way serve to replenish the commercially important stock of large fish offshore. Former markings did not throw light on this question because a large percentage of tags were lost from the fish within the first year, but since 1931 more permanent marks were used and statistically significant returns of cod that were liberated two years ago are being received. Thus far local returns have predominated, which indicates that there is no important spread of the cod from the coast of Maine before their fourth or fifth year. However, of 2,680 tagged in 1931 and 1932, 5 or 0.2 percent were returned from Georges Bank; whereas of the 12,000 comparable releases formerly made with the less permanent tag, only 0.004 percent were reported from offshore grounds. There was a similar improvement of distant recaptures along shore, which indicates that the new-style tags are more suited to the problem than the ones formerly used. It remains for future returns to indicate a more marked offshore movement, if such there be, later in the life of the cod.

WINTER FLOUNDER

Of 4,179 tagged winter flounders (*Pseudopleuronectes americanus*) released at Waquoit Bay and Woods Hole during the spawning season (January to April) of 1931, 141 were returned in 1931, 64 in 1932, and 33 during 1933. Last year's returns were consistent with those of former years; the majority were retaken during the spawning season at the place of liberation, and the remainder were reported from the adjacent sounds and the contiguous open sea during other months of the year. Half of the fish were marked with a tag placed at the nape, and half with the tag placed at the dorsal edge midway between head and tail. The marked superiority of nape tags in the third year returns indicates the greater permanence of marks placed in this position.

SHORE FISHES OF THE MIDDLE ATLANTIC STATES

These investigations were continued under the direction of R. A. Nesbit. Because of reduced appropriations it was necessary to curtail collections of data in 1933. Daily sampling of the commercial catch at important fishing centers was abandoned completely. Field operations consisted of observation of the winter trawl fishery landings at Portsmouth, Va., during January, February, and March; hatching experiments with squeteague eggs at Wildwood, N.J., in June, and tagging experiments with squeteague in Sandy Hook Bay, N.J., and of Hog Island, Va., in October, and with scup at Woods Hole, Mass., in November. In addition, Prof. A. E. Parr, in cooperation with the Bureau, continued his studies of the biology of the young of food fishes in New Jersey.

Squeteague.—In the report for 1932 it was suggested that the most important increments to the New York and New Jersey stocks of squeteague during the period 1928–32 consisted of fish which had spent their first two growing seasons south of Delaware Bay. This implies that replenishment of the northern stocks of squeteague depends a great deal less on local reproduction than on immigration from more productive southern spawning areas. Further findings during 1933 necessitate substantial modification of this view.

Although these findings strongly support the view that the great majority of the squeteague taken in the northern fishery enter that fishery for the first time as 2-year-old fish after having spent a year as yearlings south of Delaware Bay, it now appears that approximately half of these immigrant 2-year-olds originate in the North and return there after a year spent in the South. This compels a revision of the opinion that northern spawning ordinarily makes no significant contribution to northern stocks of adults. It still appears, however, that these stocks are dependent on southern spawning areas for about half of their increment.

The evidence for this modified view of the rather complex behavior of squeteague consists in part of the results of 1932 tagging experiments, in part of further analysis of scale collections, and in part of the results of a hatching experiment with squeteague eggs. These will be discussed in turn.

During the following summer 47 belly tags were returned from 1,900 juvenile squeteague tagged in October 1932, near Montauk, N.Y. Of these, 14 were taken south of Delaware Bay, 24 in or north of Delaware Bay, and 9 were not accompanied by records of date and locality of recapture. It is certain that many more tagged fish were recaptured than were reported, especially between May and September, for internal tags are not discovered unless the fish are gutted. Since the fish were small (average length 8 inches) when tagged, many were undoubtedly culled from the catch and discarded without examination. Because of the slower growth of southern yearlings, it is probable that a larger proportion of the southern than of the northern summer recaptures were not reported. Thus it is apparent that the southern yearlings which provide the bulk of the northern increment of 2-year-old fish in the following year include an unknown but possibly considerable number of squeteague which originated in the North.

More useful is the evidence from further analysis of the scale structure of fish in representative samples of the commercial catch, for it permits a quantitative estimate of the respective contributions of northern and southern spawning and nursery areas to the northern stock of adults.

The method used previously, that of comparing the early growth increments (as calculated from the scales) of northern adults with the corresponding observed increments of northern and southern juveniles and yearlings, although satisfactory for distinguishing those northern adults which have been in the South as yearlings from those which had been in the North, has not proved adequate to determine where these fish were as juveniles (i.e., fish less than a year old).

In 1933 a method was employed which appears to permit separation of the northern adults according to origin. This consists of comparing the average spacing of circuli in the first growth zone of the scales of northern adults with the spacing in the corresponding zone of northern and southern juveniles and yearlings. It was found that the northern juveniles and yearlings agree in having a significantly wider average spacing than the southern juveniles and that the frequency distribution of the spacing values of northern adults indicates a mixture in almost equal proportions of fish that have first growth zones characteristic of northern and southern juveniles. The scales of yearling fish show similar differences between the second summer zone circuli when northern and southern yearlings are compared. The great majority of northern adults, however, show second zone spacing of the southern type even though the first zone of about one-half of them is of the northern type.

In order to determine whether squeteague eggs are capable of hatching at the temperatures prevailing in the North during the spawning season, an experiment was carried out jointly by Prof. A. E. Parr and R. A. Nesbit. Squeteague eggs were found to hatch freely at all temperatures from 13° to 25° C. Since this exceeds the range of temperature observed in the northern as well as southern localities where eggs occur, it is certain that low temperatures do not, as suggested previously, prevent successful reproduction in the North. No explanation has yet been found for the uniform absence of squeteague larvae from the northern plankton collections.

Thus far the evidence for the view that the great majority of northern adults, including many that originated in the North, spend their second summer south of Delaware Bay consists of the observation that in the North yearlings are never sufficiently numerous to account for the numbers of older fish in subsequent years; of the observation that the calculated second summer growth increments of northern adults agree much better with the observed growth of southern than of northern yearlings; and of the fact that the spacing between circuli of the second growth zone of the scales of northern adults agrees with that of the corresponding zone of the scales of southern yearlings, and differs sharply from that of the scales of northern yearlings.

Direct evidence from tagging experiments is still lacking. The results of the October 1932 tagging in Pamlico Sound, N.C., indicate that in 1933 very few of these fish migrated to waters north of Virginia. In this experiment 1,900 squeteague were tagged, of which about 1,600 were yearlings or older. In the summer of 1933, 115 tags from yearlings or older fish were returned, 68 from North Carolina, 8 from Virginia and Maryland, including Chesapeake Bay, and 1 from New Jersey. Thirty-eight tags were returned without data as to the location of recapture. Since most of the latter were returned from southern markets, it is probable that the majority were recaptured in North Carolina or Virginia. The interpretation of this lack of northern returns is impossible because of the necessity for abandoning observations of the age composition of the northern catch. Previous observations have proven that increments to northern stock are irregular from year to year. In 1933 very few southern squeteague may have migrated North, in which case none of the tagged fish from the South could have been expected to show up in the North. As it is, negative evidence is not conclusive and positive evidence must be sought. In a further attempt to secure direct evidence of migration of southern yearlings 900 squeteague, about half of which were yearlings, were tagged off Hog Island, Va., in October 1933.

In order to determine the winter habitat of northern adult squeteague, 220 were tagged in Sandy Hook Bay, N.J., in October. The New York Aquarium kindly lent its collecting vessel, the *Sea Horse*, for this experiment.

Results obtained thus far indicate that if conservation measures are found necessary for maintenance of the general stocks, their application is, in the main, an interstate rather than a local problem. Any locality which imposes restrictions on the catch of marketable fish with the object of improving the future yield at the sacrifice of immediate gain must necessarily bear the whole burden of the immediate restriction but share to some extent any future gain with other localities. For example, if fishing be restricted in eastern New York during the spawning season, any resulting increase in the productivity of the spawning season must be shared with the fisheries of Virginia, Maryland, Delaware, and New Jersey. Indeed, during the season immediately following the whole benefit would accrue to these States, for of the recaptures of juvenile squeteague tagged at Montauk in 1932 not a single individual returned to eastern Long Island in 1933. That this is not exceptional behavior in that year is indicated by the persistent absence of yearlings in New York between 1928 and 1932.

There remain, however, certain local problems which merit further investigation. Foremost among these is that of eliminating the waste of yearlings in a number of southern localities during the early summer. This problem as it applies to Pamlico and Core Sounds in North Carolina was investigated by Higgins and Pearson in 1925,[2] and specific recommendations were made. The results of the 1932 tagging described above indicate that the major part of the gain would accrue locally, even in the following year. Steps should be taken, moreover, to investigate the practicability of modifying pound nets to permit the escape of squeteague below commercial size.

Among the more pressing local problems in New York and New Jersey is further investigation of the factors controlling the supply of squeteague in the many enclosed bays of these States. Thus far, the investigation has been concerned primarily with the causes of fluctuations in the general stock of squeteague on the Middle Atlantic region. It has been assumed that the supply of fish within the bays is influenced primarily by fluctuation in the general stock. It is possible, however, that there may be wide and uncontrollable variations from year to year in the proportion of the total stock frequenting the bays. It is also possible that the fishery within these enclosed areas may be so intensive as to remove fish more rapidly than they enter from outside waters, and thus produce an abnormally low level of abundance during the greater part of each season. Even severe depletion of the bays during a particular season need not be regarded as prejudicial to the future supply either in the bays or in the general stock from which the bay supply is drawn, for the number of fish in the bays appears to represent but a small proportion of the general stock. There is no reason for believing that complete removal of all the fish in the bays by the fishery would influence the future supply to any greater extent than the removal from the general stock of an equivalent number of fish from outside locations. If the commercial fishery alone were concerned, rapid depletion of the inside supply each year would be a matter of little concern, for the total number caught would in any case be limited to the number entering the bays and it would not matter whether they were caught early in the season or later.

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[2] Higgins, Elmer, and J. C. Pearson. Examination of the summer fisheries of Pamlico and Core Sounds, N.C., with special reference to the destruction of undersized fish and the protection of the gray trout, *Cynoscion regalis* (Block & Schneider). Bureau of Fisheries, Document 1019, 1927.

However, these bays not only support a commercial fishery but provide a recreational resource of great value. It cannot be determined without further investigation whether unrestricted fishing within these bays is incompatible with maintenance of satisfactory angling conditions. It may be pointed out, however, that angling in the bays at the eastern end of Long Island, N.Y., where commercial fishing is not restricted, does not appear to be less satisfactory than in the New Jersey bays where numerous restrictions are in effect.

Scup.—Investigation of this species by W. C. Neville has shown that the pound-net yield is subject to wide fluctuations caused by variation from year to year in success of reproduction. Complete recovery of the pound-net yield in the period 1929–33 from the low levels of 1926–28 demonstrates that under the conditions prevailing until 1929 the fishery was not taking undue toll of the stock. Since 1929 an additional toll of about 25 percent has been taken from the stock by the winter trawl fishery off the Virginia Capes.

As in 1932, attention was focussed on determination of the effects of the increased strain. Thus far there appears to be no evidence of ill effects. Four of five recent spawning seasons, 1927, 1928, 1930, and 1931, are known to have been successful and there is evidence that the 1932 season was productive as well. As a result the yield of the summer fishery remains high. Hence, it is apparent that the combined effects of the summer and winter fisheries have not reduced the numbers of spawning adults sufficiently to prevent successful spawning.

It is not to be expected, however, that all future spawning seasons will be productive. Experience suggests that sooner or later conditions similar to those of 1926–28 will again obtain. Under such conditions the increased strain of the combined fisheries may assume a serious aspect. There remain many facts to be ascertained, if the Bureau is to be prepared to make sound recommendations for the protection of the fishery when the need arises. Particularly is this true of the winter fishery where remarkable and as yet not fully understood changes in the locality and composition of the catch have occurred.

It is desirable, therefore, that the present observations of the winter fishery be continued and that observation of the summer fishery be resumed.

IMPROVEMENT OF INVESTIGATIONAL SERVICE

This report would not be complete without mention of the things most urgently required to facilitate the acquisition of biological facts necessary for the conservation of the fishery resources of this region.

The principal impediment to progress at present is the lack of assistants to analyze the statistics of the fishery and the biological records necessary for their interpretation. Practically every determination of changes in abundance, average differences in growth rate, and the like involve the handling of mass data, such as the daily catch of a large number of boats over an extensive area throughout a considerable period of time or the summation of large numbers of measurements of fish or of fish scales. The purely clerical work involved in the reduction of such mass data to comprehensible terms attains a magnitude not usually appreciated. Furthermore, more frequently than not, during the course of study the need for additional data from the fishery becomes necessary and progress is halted until the investigator himself can spend the weeks or months necessary to collect them. Here again the provision of assistance would facilitate the work greatly. Due to lack of assisting personnel, both in the laboratory and in the field, the results reported above are fewer in number and much less definite in purport than would have been the case if adequate assistance were available. Under the circumstances it is readily apparent that a very small increase in the salary roll necessary to provide the appropriate assistance would double the value of results by increasing their number and their significance.

Secondly, the lack of a suitably equipped research vessel capable of offshore work has been a very serious handicap. While data collected ashore on the fish brought in by fishing vessels and at sea on commercial fishing craft must always provide the basic material for determining the condition of the resource, the interpretation of these facts requires also the kind of data that can only be secured at sea by a vessel equipped to handle hydrographic instruments, special nets and trawls, and free to survey the particular grounds that must be examined to elucidate the phenomena occurring in the fishermen's catches.

Thirdly, the restoration of activities at the United States Fisheries Biological Station at Woods Hole is needed to complement the regular investigative program. Just as data at sea are necessary to elucidate the peculiarities of yield exhibited by fishermen's catches, laboratory experiments are often required to discover certain basic features of the life processes of fishes and their responses to certain environmental conditions. At the Woods Hole station many of these studies could be pursued by volunteer investigators from universities at no expense to the Government beyond those incidental to care and maintenance of the equipment of the establishment.

FISHERY INVESTIGATIONS OF THE SOUTH ATLANTIC AND GULF COASTS

INVESTIGATION OF THE SPAWNING HABITS, LARVAL DEVELOPMENT, AND RATE OF GROWTH OF FISHES

The study of collections of young fish and field data collected principally on the coast of North Carolina was continued during the first several months of the year by Dr. Samuel F. Hildebrand assisted by Louella E. Cable. A comprehensive manuscript, illustrated with drawings prepared by Miss Cable, on the spawning habits, the larval development, and rate of growth of several species of the family consisting of the croakers, drums, king whiting, and weakfish or sea trouts (Sciaenidae) was completed and submitted for publication. This paper includes keys for the identification of young Sciaenidae of the South Atlantic and Gulf coasts of all the species for which the young are known.

The study of the general collection of young fishes from the South Atlantic was continued. Complete or almost complete series, showing the different stages of development, for several species were found. Drawings were prepared for some of these series.

A young tarpon only about 20 millimeters, in transition from the leptocephalus to the adult stage, was found in the collection. The young of this fish heretofore were unknown entirely. A description, with notes, of this young tarpon was prepared and submitted for publication.

A SURVEY OF THE FRESH WATERS OF MISSISSIPPI

A general survey of the fresh waters of the State of Mississippi was begun by Dr. Hildebrand in cooperation with the State Game and Fish Commission. The investigation was conducted for the purpose of determining the status of the fisheries and to study the life histories and spawning habits of the fishes of the State, with the view of gaining information that would be useful in preparing proper regulatory measures and in building up and conserving the fisheries.

The fisheries in general were found to be in a fair to good condition. As Mississippi is still largely rural, the drain on the fisheries has not been as pronounced as in some other States where there is a greater concentration of population. Neither have the waters been as seriously polluted in Mississippi as in many other States. However, in some sections of the State the fisheries have suffered severely because of deforestation and drainage. This has caused fluctuations in the stages of the streams decidedly detrimental to the fish fauna.

A lively interest in fish and fishing was manifested in all sections of the State visited, and an earnest desire prevails on the part of many citizens to build up and conserve this resource.

A report on the investigation embodying notes on the life history and habits of the fishes, recommendations for the improvement of certain waters, and suggestions for improved regulatory measures was prepared. The study of the fishes and data collected is being continued with the view of preparing a catalog and general account of the fishes of the State.

MARINE FISHES OF THE GULF COAST

Continuing his studies of the marine fish fauna of the Gulf coast, Isaac Ginsburg has been engaged during the year in examining collections of fishes from many localities and in revising the taxonomy and classification of a number of families among which confusion exists in the literature as a necessary preliminary to the preparation of a monograph on the fishes of the whole region.

The systematic study of the flounders occurring in American waters was carried forward and continued during 1933, especially those species which are related to the important commercial genus of *Paralichthys*, since for a complete understanding of the status of the species of this genus, it is important to fix definitely the morphological limits of related species. Further studies on the species of *Paralichthys* were also carried out. As a result of these studies a preliminary report on some of the species was published in the Proceedings of the United States National Museum.

Studies were also made on the systematics of two families of the smaller fishes, namely, gobies and seahorses. These fishes are common and form a regular feature of the littoral marine fauna. On account of their common or frequent occurrence they of necessity must play an important role in the complex interrelationship of the littoral marine fauna.

SHRIMP INVESTIGATIONS

During 1933 the shrimp investigations have continued as in the past under the direction of Dr. F. W. Weymouth of Stanford University and Milton J. Lindner. Curtailment of funds resulted in the dismissal of Gordon Gunter and a clerical assistant in June, but John C. Pearson, assistant aquatic biologist, was transferred to the staff at this time.

Through the excellent cooperation of the Louisiana Department of Conservation, the Texas Game, Fish, and Oyster Commission, and the Georgia Tidewater Commission the major portions of the shrimp investigation program have been continued in spite of a reduced budget. Headquarters have been maintained at New Orleans, La., in offices furnished by the Louisiana Department of Conservation, with field stations at the United States Fisheries Laboratory, Beaufort, N.C., the Georgia Tidewater Commission, Brunswick, Ga., and the San Patricio Canning Co., Aransas Pass, Tex.

Although three species of shrimp occur in the fishery through most of its range, which extends from North Carolina to the Mexican border, the investigations at present are being directed mainly toward solving problems concerning the life history of the common shrimp (*Penaeus setiferus*). This species is by far the most important because it comprises over 95 percent of the commercial catch. The other two species, the grooved shrimp (*P. brasiliensis* and the sea bob (*Xiphopenaeus kroyeri*), each furnish about 2½ percent of the catch.

At Beaufort, N.C., Dr. J. S. Gutsell has continued his collections of young and adult shrimp. In addition, he is studying the histological development of ovarian eggs of the three species of shrimp in an attempt to delimit more closely the spawning times and places.

During 1933 the South Atlantic work carried on by W. W. Anderson at Brunswick, Ga., was extended to cover the entire coast from Charleston, S.C., to Cape Canaveral, Fla. This program was initiated in May after an exploratory trip to the Cape Canaveral grounds in January had indicated the possibility of extensive movements of the shrimp along the South Atlantic coast during late fall and winter. Nine stations were established along this 300-mile stretch of coast, as follows: Stono Inlet, S.C.; Gaskins Bank, S.C.; St. Catherines Island and Brunswick, Ga.; Fernandina, Mayport, St. Augustine, New Smyrna, and Cape Canaveral, Fla. The stations are distributed from 1 to 6 miles off the places mentioned. Each locality was visited once every month and 2 or 3 hauls of 1 hour each were made. In addition, the inside waters consisting of the creeks, rivers, and sounds, in the vicinity of Brunswick, were trawled for shrimp each month.

Analysis of the data gathered at these stations indicates that there are no important nursery grounds for the common shrimp south of St. Augustine, Fla., while the reticulated coastal sections of Georgia and northern Florida appear to be the major nursery area of the South Atlantic. This observation tends to corroborate other evidences which imply that the postlarval shrimp that spawn in the ocean or Gulf of Mexico and pass their larval stages there must reach the inside waters at an early stage in order to survive. Additional work is needed to substantiate this point definitely.

Length frequency distributions of the common shrimp along the Georgia coast during the fall and winter of 1931–32 and 1932–33 show a definite disappearance of the large shrimp (above 140 millimeters) from the fishery areas. During both years this disappearance began with the onset of cold weather in October and reached its maximum in January and February. Coincident with the disappearance of the large shrimp from the Georgia grounds there arose a fishery in the vicinity of Cape Canaveral, Fla. This Florida fishery usually reached its maximum in January and rapidly declined thereafter until by the latter part of March only a remnant remained. The January (1933) trip to these southern grounds disclosed the fact that the shrimp population at Cape Canaveral was composed almost exclusively of large shrimp, for over 97 percent were above 140 millimeters and 62 percent were between 156 and 170 millimeters.

This evidence would indicate a southward movement of the large shrimp throughout the fall and winter with a concentration near Cape Canaveral. However, during the fall and winter of 1933, although the scarcity of large shrimp was as evident along the Georgia coast as in the previous two years, the Cape Canaveral fishery failed to materialize to the extent it had during the previous two winters. This leads to four possible hypotheses: (1) The movement of shrimp is not from north to south, but from inshore to offshore waters; (2) the large shrimp at Georgia points were depleted during the summer and early fall fishery, consequently only a few remained to move south; (3) instead of wintering near Cape Canaveral as in recent seasons the shrimp moved further south along the Florida coast and out of the customary fishing grounds; (4) the shrimp migrated south to Cape Canaveral, but because of colder waters along the coast moved offshore to warmer waters nearer the Gulf Stream.

Because of the lack of data over a sufficient number of months, it is impossible to state at this time which of these hypotheses represents the true situation. It is extremely important that the present studies, with some modifications, be continued in order to arrive at a correct solution of the problems involved as they are of vital importance economically and biologically.

In addition to the above, the South Atlantic operations have yielded sufficient information to allow the projection, for the first time, of what appears to be a normal growth curve. The constant influx of young shrimp into the fishery and the continual movements of the shrimp from place to place have made this impossible in the past. Application of this curve to data gathered along the South Atlantic and Gulf coasts indicates that there may be a longer spawning season than at first suggested and also that there may be two peaks of spawning, one in winter and the other in late spring and summer.

In Texas, Kenneth H. Mosher has continued the sampling of the commercial catch of shrimp at Aransas Pass. In addition, the Texas program has been extended along the coast to cover the major shrimping ports monthly. In each locality a random sample of shrimp is taken from a number of fishing boats. The shrimp are sexed, measured, and the degree of maturity noted.

An analysis of the Texas lighthouse temperature records including Sabine Pass Light, Galveston Jetties Light, Half Moon Reef Light, Aransas Pass Light, and Brazos Santiago Light, indicates an inshore cold water barrier near Point Isabel, Tex., that averages 20° F. colder during the summer and 10° F. colder during the winter than any of the more northern Texas points. Because of the lack of sufficient offshore water temperatures adjacent to Point Isabel, it is difficult at this time to state how representative the water temperatures at Brazos Santiago Light are of the conditions in the Gulf near Point Isabel. The occurrence of a cold water barrier in this locality would have considerable influence on the coastwise movement of shrimp, fishes, and other marine life in southern Texas and northern Mexico.

In Louisiana, owing to decreased funds, the collecting trips of the Bureau's research vessel *Black Mallard*, which is maintained by the Louisiana Department of Conservation, were reduced to 1 a month but of slightly longer duration, instead of the customary 2. John C. Pearson has examined the entire plankton collections secured since the inauguration of the study in Louisiana and has found that young postlarval *Penaeus brasiliensis* occur in the surface offshore tows throughout the winter, spring, and summer, which indicates an extended spawning season for this species. Although *P. setiferus* is much more abundant than *P. brasilensis*, no postlarval young of this species have been secured in the surface tows. From this evidence it is believed that the young stages of *P. setiferus* are demersal. The recent addition of new hoisting equipment allows for the operation of subsurface and bottom fine mesh nets. Consequently, it is expected that during the coming spawning season the young stages of *P. setiferus* will be found in considerable abundance in the offshore waters.

Body proportional measurements of *Penaeus setiferus* in Louisiana indicate the possibility of two groups or races of common shrimp. This work is still in a formulative stage and must be continued over a longer period of time and in more localities before definite conclusions can be drawn.

In Louisiana and Texas a disappearance of large *Penaeus setiferus*, similar to that in Georgia, takes place during the winter. In these two States there is no winter fishery for large shrimp, such as occurs in Florida, to indicate where the winter habitat may be. At the onset of colder weather in the fall the shallow coastal waters of Louisiana cool rapidly to a distance of about 10 miles offshore. Further offshore, beyond this variable zone, bottom temperatures are higher. As greater depths are reached, however, bottom temperatures of the Gulf again decline. Consequently, there is a zone of warm bottom water off the Louisiana coast throughout the winter bounded on one side by colder inshore waters and on the other by the cold waters of the depths of the Gulf. The recent addition of a winch to the *Black Mallard* has allowed collecting cruises in this warm water zone as weather permitted. Both large *P. setiferus* and *P. brasiliensis* were found in this area during the winter of 1933. Collecting trips are made throughout this warm water zone off Louisiana whenever possible in an effort to determine whether or not shrimp concentrate in dense schools in certain offshore localities as it is customary for them to do inshore. With the present type of vessel it is exceedingly difficult to make any intensive survey of offshore waters because rough seas are prevalent throughout most of the winter.

The grooved shrimp, *Penaeus brasiliensis*, evidently spawns most prolifically in the Gulf throughout the winter for during December, January, February, March, and April an abundance of postlarval young are taken in the surface plankton tows. From March until June the young grooved shrimp which were spawned in the Gulf are found in large quantities in the inside waters along the entire Louisiana coast. As they develop, the grooved shrimp disappear from the inside and adjacent offshore waters and few remain by July or August. These shrimp, with few exceptions, cannot be found until the following winter when a newly hatched group of young appears. During the winter of 1933 large, mature grooved shrimp were obtained in nearly every haul in the offshore warm water zone. This fact indicates that the inside waters serve not only as nursery grounds for the common shrimp but for the grooved shrimp as well. The grooved shrimp, however, move offshore at an earlier stage than the common shrimp. With the present geographic limitations of the fishery, the young grooved shrimp leave the fishing areas before they have reached sufficient size to be of much commercial value.

Except for the detailed accounts of one cannery, it has been impossible to secure adequate catch records to determine the relative abundance of the shrimp. The data which have been obtained do not indicate serious depletion of the supply, but this fact does not indicate that depletion will never occur. On the contrary, because of the short life of the common shrimp, which is believed to be only 1 year, it is possible that depletion can become a serious problem. Consequently, it is recommended that all States utilizing shrimp commercially provide for records of the catch suitable for purposes of abundance analysis. Louisiana is the only State which has taken steps toward this goal. The Louisiana Department of Conservation recently inaugurated a system whereby any person receiving shrimp directly from a fisherman must complete a form furnished in triplicate by the State. The completed form gives the following information: The date, the name of the person receiving the shrimp, the name of the fisherman or captain, the name and registration number of the boat, the approximate locality of the catch, the type of gear (seine, trawl, or cast net) used, the length of the net used, the amount of shrimp received, and the price paid for them. The original is given to the fisherman, the first carbon retained by the purchaser, and the second carbon held by the purchaser until collected by an agent of the conservation department. In this way the required information is obtained daily on each catch of shrimp by every fisherman.

If this system is continued in the proper manner, it should be possible within a few years to determine closely any annual fluctuations in the abundance of shrimp in Louisiana. A definite knowledge of the abundance of shrimp is not only of benefit to the State, in that when depletion occurs it may be detected in its early stages and proper remedial actions taken, but also such knowledge is of great benefit to the industry because it will tend to prevent the enactment of restrictive measures when they are not required.

It is strongly urged that the other States of the South Atlantic and Gulf area follow the course of Louisiana and adopt adequate statistical systems for the ultimate benefit of the State and of the industry.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

The major salmon and herring investigations carried on by the staff of the Fisheries Biological Station at Seattle, Wash., were continued during 1933. Although the field activities of these investigations are confined to definite localities in Alaska and on the Pacific coast, they all have as their common goal the study of the causes responsible for the fluctuations in the abundances of these species with the aim of providing for permanent and productive fisheries throughout the entire region.

The development of two power dam projects on the Columbia River during the past year necessitated a study of the ways and means of protecting the migratory fish at the dams. During the summer and fall a survey was made of the salmon and trout populations in the Columbia River and its tributaries in the vicinity of the dam site for the Grand Coulee Dam in the State of Washington. The results from this survey were used as a basis for recommendations concerning the protection of the migratory fish at this dam. In the latter part of November, Harlan B. Holmes, one of the members of the station's staff, was temporarily assigned to the study of the ways and means for protection of migratory fish at the Columbia River Dam at Bonneville, Oreg.

KARLUK RED-SALMON INVESTIGATION

The biological investigation on the Karluk River red salmon, conducted by J. T. Barnaby, was continued during the past year. The prime purpose of this investigation is the determination of the ratio between the spawning escapement and the return from that escapement; the determination of the fluctuations occurring in these ratios from year to year; and the causes for such fluctuations. A thorough knowledge of the magnitude of these fluctuations and their causes will enable an economically sound regulation of this fishery as well as of other fisheries of a similar nature.

Another marking experiment was initiated, 40,000 seaward migrants being marked by the amputation of the two ventral and the adipose fins. The returns from this experiment will appear in the runs of 1934, 1935, and 1936. The 1933 run was sampled throughout the season for the purpose of recovering fish marked in previous years; 178,080 fish were carefully examined and 931 marked fish recovered. These marking experiments will, when completed, enable the determination of the fluctuations in the ocean mortality of these red salmon, the calculation of the number of seaward migrants during the year each experiment was initiated, and the calculation of the mortality rate during the time these fish spent in Karluk Lake.

Scale samples were taken throughout the season for the purpose of determining the age composition of the run. A weir was again operated in the Karluk River and the age composition of the escapement can also be calculated from the data thus obtained.

Special attention is being given the data collected to date in respect to returns from known escapements to ascertain to what extent heredity influences the time of migrating to the ocean and the time of returning to spawn. There is a considerable degree of variation from year to year in the age composition of the runs and likewise of the escapements. It is felt that this study, together with the limnological investigations being carried on at Karluk Lake, will, at least to some extent, clear up the problem of why escapements of similar magnitudes produce different-sized returns.

Two trips were made to Karluk Lake, one during July and one during October, at which time spawning-ground surveys were made and limnological data collected.

In addition to the red-salmon run, the Karluk River supports a run of pink salmon of considerable importance. With a normal escapement, the pink salmon occupy the spawning grounds in Karluk River proper and none enter Karluk Lake to continue on to the red-salmon spawning beds. Thus, while both species spawn in the same watershed, their spawning grounds are distinct. Occasionally, however, due to a series of conditions unusually favorable to the pink-salmon population, certain brood years produce extremely large runs. At such times population pressure forces some of the pinks to continue on to the red-salmon spawning grounds. In years when the number of pinks on the red-salmon spawning grounds is not large, no harm is done. However, at times when there is a relatively large escapement of pink salmon there is not only overcrowding on the pink-salmon spawning grounds, but serious overcrowding on the red-salmon spawning grounds. This condition may be severe enough to result in almost total loss of all pink-salmon spawn, and a very serious loss of red-salmon spawn through the suffocation of unspawned pinks and reds and damage to the eggs already laid in the gravel beds.

A report submitted to Commissioner Bell pointed out that although the data for use as the basis for the prediction of a future run of pink salmon are meagre, all the evidence at hand points to an extremely large run of that species to the Karluk River in 1934. Recommendations were submitted as to the most advisable remedial action in case a large run does materialize.

CHIGNIK RED-SALMON INVESTIGATION

An investigation of the red-salmon runs of Chignik River, Alaska, was continued by Harlan B. Holmes, assisted by George B. Kelez. As a result of shortage of funds, field work was restricted to what could be done by one man. This consisted essentially of collecting routine data relating to the season's run of mature fish and recovering mature fish that had been marked as fingerlings.

The principal object of this investigation is to determine the number of fish that should be permitted to spawn each year so as to produce the greatest surplus for the commercial fishery in the succeeding generations and at the same time protect the run. The procedure has been to observe the results of propagation of varying numbers of spawners. With a few minor interruptions, the number of spawners has been counted each year from 1922 to 1932. In 1933 high water prevented counting.

As a significant proportion of the fish do not mature until in their sixth year, returns from only the first six broods are now available. Complications in the life and habits of the fish have delayed exact analysis of the results. Tentative interpretations suggest that the relation between number of spawners and number of adults produced is not as regular as we hoped to find it. The ratio of number of spawners to return has varied from approximately 1/1 to 1/7. The largest ratio accompanied the smallest number of spawners, but the smallest ratio did not coincide with the largest spawning escapement. The largest total return was produced by the largest spawning escapement, but in contrast to this the second largest escapement produced the smallest total return. It, therefore, will be impossible to state, even approximately, the most desirable number of spawners until more experience is available. It is hoped that in the meantime we may acquire a greater knowledge of the life of the fish and the conditions that affect their mortality, both of which will permit more exact analysis of the data and application of the findings to other streams.

A peculiar feature of the Chignik red salmon is the fact that fingerlings are found in the river below the lakes from May through September or later. In other streams the fingerlings are found in the lower river only during a short period of seaward migration. It first was presumed that the seaward migration at Chignik extended for the 5 months. As it was realized that such a long migration period would result in scale characters that would be confusing in age determination from the adult scale, 65,000 of the presumed migrants were marked in 1929. The marking was divided into three lots, the fish in each lot being distinctively marked. The first lot represented fish caught between May 29 and July 4; the second lot from July 11 to July 24; the third from August 16 to August 26.

The mature fish from this marking, which returned to spawn during 1932 and 1933, have added interesting anda valuable information to our knowledge of their life and habits. Among the returns from the first lot 67 percent continued on to the ocean during the year in which they were marked, whereas the remaining 33 percent lingered an additional year in fresh water. Of the second lot only 4 percent migrated during the year of marking and 96 percent remained in fresh water for an additional year. In the third lot only 3 percent migrated and 97 percent remained for another year. These observations indicate that the seaward migration is confined essentially to the early part of the season and that for the remainder of the season the fingerlings found in the river—even down to the entrance of the estuary—must return to the lake before winter. Preliminary returns from marking in 1930 and 1931 confirm these findings and indicate that this peculiar habit is a regular occurrence.

BRISTOL BAY RED-SALMON INVESTIGATION

Although funds were not available for a biologist to carry on field work in Bristol Bay during the past year, scales of the 1933 red-salmon populations in this area were secured through the cooperation of the Alaska Division of the Bureau. Scale samples and body measurements of the red salmon composing the runs in Bristol Bay have been accumulating for a number of years. These data were studied by Dr. Frances N. Clark at Stanford University during the past year. Dr. Clark analyzed the data from the Nushagak area of Bristol Bay, and included in a report the results of this analysis together with recommendations for future investigations in this area. This report, " Red salmon in Nushagak district, Bristol Bay ", is now on file in the Washington office.

PUGET SOUND SOCKEYE INVESTIGATION

The study of the fluctuations in abundance of sockeye salmon of Puget Sound in the State of Washington was continued during the past year, under the direction of J. A. Craig. For the purpose of this investigation, a statistical study has been made of the catch return of a constant unit of gear fished during a constant period of time.

Total catch or pack records are often inaccurate and at times even misleading when used for the purpose of judging the relative abundance of a population of fish over a period of years. This must necessarily be so when it is evident that economic conditions, changes in total fishing effort, legislation, or a change in fishing methods might cause fluctuations in the total catch of any species quite apart from any changes that might have occurred in actual abundance.

Records of the daily catches of a selected group of traps in Puget Sound were collected and analyzed on the basis of the average catch per trap per fishing day, thus providing a constant unit of fishing gear and time. When these records were analyzed and compiled in the form of an index of abundance, the index indicated a marked drop in the abundance of the Puget Sound sockeyes from 1917 to 1932, inclusive.

A detailed inspection of the daily fluctuations in abundance of the sockeye salmon during each fishing season indicates that the middle portion of the season, which at one time provided a large part of each season's catch, has suffered the greatest decline. This may be very significant, since from previous studies of red or sockeye salmon it appears that each tributary of a large river system such as the Fraser, which provides practically all of the Puget Sound run, may support a separate race or population of sockeye salmon each of which has a definite time of migration into the stream. Therefore, this decline of the middle portion of the run may indicate that certain races are being more rapidly depleted than others and are in need of protection.

Scale samples were taken during the past fishing season. These will be studied in a attempt to link scale characteristics to the seasonal fluctuations in the run. If this can be accomplished, the degree of racial differentiation during the season can be established, and possibly some of the races identified in the commercial fishery and their spawning grounds determined.

Marked fish from the Birdsview, Wash., marking experiments of 1929, 1930, and 1931 were recovered from the commercial catch during the past season. This experiment was carried on for the purpose of determining the most favorable time for the liberation of hatchery-reared sockeye salmon.

PINK-SALMON INVESTIGATION

The pink-salmon investigation in southeastern Alaska, under the direction of Dr. Frederick A. Davidson, was continued during the past year and included a cooperative project with the National Canners Association of Seattle in addition to the regular program of activities.

One of the natural handicaps encountered in the pink-salmon fishery is the rapid decrease in the quality of the salmon as they become sexually mature. With the onset of sexual maturity the male pink salmon develops an enormous hump on his back and a greatly elongated grotesque head. The hump is composed mostly of cartilage and is grown at the expense of the fatty and muscular tissue of the back. The female pink salmon, on the other hand, changes very little in body form with sexual maturity but owing to the heavy drain imposed upon its stored energy, by the maturation of the eggs, it likewise deteriorates in condition very rapidly. In fact as both males and females become sexually mature their flesh becomes soft and loses practically all of its fat content and red coloration.

When the pink salmon migrate into the inside waters of southeastern Alaska, they practically cease feeding and depend upon their stored energy for maintenance and growth during the remainder of their life cycle. The pink salmon that appear in the first part of the season are sexually immature and draw upon their stored energy only for the purpose of maintenance during their migration to the spawning grounds. As the season progresses, however, the salmon composing the runs begin to show signs of sexual maturity while still in the waters subject to the commercial fishery. Hence these salmon draw upon their stored energy for maturing the sexual products as well as for maintenance during their migration. It is owing to this double drain upon their stored energy that the pink salmon entering the commercial catch during the latter part of the season are of poorer quality.

The percentage fat content and degree red coloration in the flesh of the Pacific salmon have for years been used as a market standard for quality. Hence, any information concerning the seasonal change in these measures of quality in the pink salmon would be of value to the cannerymen in grading their packs. It is for this reason that the National Canners Association of Seattle cooperated with the Bureau in a project aimed to determine the change in the percentage of fat content and degree of red coloration in the pink salmon entering Snake Creek at Olive Cove, Alaska, during the past summer. Ten pink salmon were taken at random from the run each day during the season. These fish were first measured in order to estimate their state of sexual maturity as indicated by their body form. A proportionate cut was then taken from each fish and canned in a half pound can. At the close of the season these canned samples were turned over to the National Canners Association to be analyzed. Each canned sample of fish bore the date it was taken and the sex of the fish so that the chemical analysis will indicate the change in the composition of both sexes throughout the season. The results from the analysis of the change in the body form of the pink salmon show that sexual maturity began to appear in the salmon at the beginning of the third quarter of the season. The results from the chemical analysis of the samples have not as yet been completed.

The study of the racial characteristics of the pink salmon composing the runs in Snake Creek and Anan Creek in southeastern Alaska were continued during the past summer. The data collected for this study during the past summer will complete the data necessary for the study of the racial characteristics of the pink salmon in these streams for two complete life cycles; viz, the 1930–32 cycle and the 1931–33 cycle. The results from this study thus far point very definitely to a racially distinct population in each stream. There is also some indication that the even- and odd-year populations in each stream are likewise distinctly different. The analysis of the data collected this year will make it possible to draw definite conclusions in regard to the individuality of the odd- and even-year populations in each stream.

HERRING INVESTIGATION

In December 1933 the herring investigation, under the direction of Dr. George A. Rounsefell, assisted by Edwin H. Dahlgren, submitted to the Bureau a report on the races of herring in southeastern Alaska. The populations of herring were studied by analyses of vertebral counts, growth rates, the proportions of various year classes and by the recovery of tagged herring.

In analyzing the vertebral counts only counts of herring of the same year class were compared as it was shown in a previous report on the herring of Prince William Sound, and is too apparent in these data to need proof, that the mean vertebral count differs between herring of different year classes from the same locality. Segregation of the material by year classes has not been followed in the European racial work on herring, which fact doubtless accounts for many of the inconsistencies in results.

In order to be certain that grouping the samples by localities would not in itself bring out differences that were really due merely to random sampling two tests were first made to determine if the data as a whole were homogeneous. The first test was to determine whether or not any correlation exists between the mean vertebral count in the various localities of one particular year class and the temperature during the spawning period of each locality. High negative correlations were found for the 1927 and 1926 year classes, respectively. The second test was to analyze the variances of 158 samples of the vertebral count in the manner shown by R. A. Fisher, after first discarding four of the samples whose variances exceeded the normal range of variances. This test showed very conclusively that the samples are not homogenous, and that the differences between the means are too great to be assigned to chance sampling.

Application of the same test to the samples from each of seven major localities gave opposite results. In each case all of the differences between the means of samples could be assigned to random sampling. This also was in accord with the assumption that different localities might possess different populations of herring.

Comparisons of the means of the vertebral count from the various localities revealed three groups of herring that differ significantly from their neighbors: namely, Petersburg, Noyes Island and vicinity, and the localities east of Clarence Strait and south of Sumner Strait including Wrangell.

Comparisons of the length distributions of herring of the same year class show that herring of four localities: the Noyes Island area, the Douglas Island-Icy Strait area, Affleck Canal and Peril Strait are all much slower growing than those from the other localities. The Peril Strait herring appear to be the slowest growing of any yet encountered in Alaska, the median of the 4-year olds taken in June 1930 being only 176 millimeters.

Comparisons of the age distributions of purse-seined material (avoiding the selected distributions derived from gill-netted samples) caught in 1929 and 1930 show (1) the 1926 year class to be overwhelmingly dominant in most of the localities, (2) the 1926 and 1927 year classes to be approximately equal at Noyes Island, (3) the 1927 year class to be very dominant in Peril Strait, (4) the 1926 and 1923 year classes both dominant at Douglas Island and at Favorite Bay, (5) a large percentage of the catch older than the 1923 year class at Douglas Island. These facts support the evidence given by the vertebrae and the growth rates which separate the Noyes Island area, Peril Strait, and the Douglas Island-Icy Strait area from neighboring localities.

During the fishing season of 1933 (June 1 to Sept. 30) 101 belly tags and 7 opercle tags were recovered from 2,499 of the former and 1,470 of the latter affixed to spawning herring released at Jamestown Bay (Sitka) between April 21 and April 25, 1933. All of these tags were recovered around Cape Ommaney, between Larch Bay and Port Alexander, giving the first definite proof of a migration of some length, as it is approximately 66 miles by water from Jamestown Bay to Port Alexander.

On the other hand, out of 996 belly tags and 824 opercle tags affixed to herring released at Cape Bendel, just under 60 miles from Port Alexander, on August 17, 1932, no tags have been recovered. This may be considered rather definite evidence of a lack of migration between Cape Bendel and Cape Ommaney.

In another tagging experiment at Auke Bay near Juneau, 800 belly tags and 772 opercle tags were affixed to spawning herring released on May 3, 4, and 5, 1933. No recoveries have been made supporting the previous conclusion of a lack of migration between Juneau and Cape Ommaney.

The recovery in the Jamestown Bay (Sitka) tagging experiment of 4 percent of the belly tags and only one-half of 1 percent of the opercle tags clearly demonstrates the superiority of the former. The maximum lengths of time elapsing from time of tagging to time of recovery were 149 days for belly tags and 147 days for opercle tags. However, when the fishing season ended on September 30, 1933, the belly tags were being returned at approximately the same rate as at the beginning of the season so that the recovery of more 1933 tags is confidently expected in 1934.

The tagging experiments represent the first successful attempt at tagging a clupeoid fish, and it is likely that this method can be applied to the sardine, the menhaden, and other clupeoids.

INVESTIGATIONS CONCERNING THE PROTECTION OF MIGRATORY FISH AT POWER DAMS ON THE COLUMBIA RIVER

Grand Coulee Dam investigation.—It is proposed to construct a dam approximately 370 feet in height across the Columbia River at the Grand Coulee. This site is some 140 miles upstream from the Rock Island Dam and approximately 150 miles south of the Canadian border.

J. A. Craig and Harlan B. Holmes were detailed to make a study of the possible effect of this dam on the salmon and trout of the Columbia River. The number of salmon and steelhead trout passing over the Rock Island Dam were counted from July 21 to August 27, inclusive. A survey was then made of the spawning streams between Rock Island and the Grand Coulee site so that an estimate of the number of fish spawning between the two locations could be made. All available data were collected on the magnitude of the runs at points above Grand Coulee. From these data it was estimated that the run which would be intercepted by the Grand Coulee Dam may be as small as 5,000 to 15,000 chinook salmon and an undetermined number of steelheads.

Recommendations for the protection of these runs were submitted to the Fish and Game Commissions of Washington and Oregon for their approval. Because of the great height of the dam with its consequent danger to downstream migrants, it was felt that provision should be made to capture upstream migrants, spawn them artificially and liberate the offspring below the dam.

Bonneville Dam fishway investigation.—As a part of its public works program, the Federal Government is constructing on the Columbia River at Bonneville, Oreg., a dam to generate electric power and facilitate navigation. This dam will intercept annual runs of salmon, trout, and other fish valued at several million dollars a year. The passage of these fish over the Bonneville Dam will involve the greatest problem of fishway construction that ever has been attempted. It is unfortunate that past experience with fishways for a great part has not been satisfactory and we cannot point with assurance to devices that can be relied upon to pass this large mass of migratory fish over the dam.

A portion of the funds allotted to the construction of the dam has been assigned to the Bureau of Fisheries for the purpose of devising means of passing the runs of fish. Harlan B. Holmes, who has been placed in charge of the work, is being temporarily assisted by experts in various of the engineering and biological phases of the work. The investigation is being conducted in close cooperation with the commercial fishery interests and Fish and Game Departments of the States of Oregon, Washington, and Idaho.

As the work has been in progress for only about a month, no results are available as yet. The investigation will involve a study of the statistics of the fishery for the purpose of determining the time and magnitude of the runs. All types of fishways that have been used or proposed are being carefully studied. Experiments are being conducted to determine if the fingerling salmon and trout will be injured in passing through the power wheels. In case it is deemed necessary to prevent the fingerlings from passing through the wheels, means of diverting their migration will be studied and suitable bypasses provided. A careful study will be made of conditions during the period of construction so as to assure free passage of the fish at that time.

GREAT LAKES FISHERY INVESTIGATIONS

Owing to the severe curtailment of the budget no field work of any kind was conducted on the Great Lakes during the calendar year 1933, with the exception of one small project carried on by a member of the Great Lakes staff during the period April 3–14 at Sandusky, Ohio. Efforts were therefore devoted entirely to working up in the laboratory the tremendous amount of data that had been accumulated during the field investigations in past years and to prepare them for publication. Fishery investigations on the Great Lakes, under the direction of Dr. John Van Oosten, are conducted from headquarters and laboratories furnished by the University of Michigan at Ann Arbor.

During the year Dr. Stillman Wright completed a voluminous report on “A limnological survey of western Lake Erie with special reference to pollution.” This report covers a series of investigations begun by the State of Ohio in 1926 and completed in cooperation with the Bureau in 1930. The report includes sections on physical limnology, chemistry, bacteriology, phytoplankton, zooplankton, bottom organisms, and pollution in its relation to the fisheries. After a detailed consideration of these various technical subjects it was concluded that pollution in the western part of Lake Erie was not the primary or controlling factor in the depletion of the fishery in this lake. Dr. Wright also studied a series of plankton collections taken by the Bureau's investigators from certain lakes in Alaska. Owing to curtailed appropriations Dr. Wright left the Government service on June 3 and was immediately engaged by the Government of Brazil to conduct limnological surveys in the northeastern part of that country.

Progress has also been made in the further analyses and compilation of the data secured during the chub-net investigation of Lake Michigan and the deep trap-net investigation of Lake Huron and Lake Michigan (for details see report for 1932). It is gratifying to report that on the basis of the data secured during the deep trap-net survey, important regulations were passed by the Legislature of the State of Michigan that will safeguard to a large extent the seriously threatened depletion of the valuable whitefish, especially in Lake Huron.

During 1933 the Bureau continued its cordial relations with the various Great Lakes States and provided them with considerable information and scientific data concerning the commercial fisheries. Many memoranda on various fisheries problems were requested by and prepared for officials of several conservation departments; and considerable assistance was also rendered them in preparing outlines for field investigations, in drawing up fishery regulations, and in furnishing expert testimony at public hearings called by legislative committees. In fact, the Bureau's office at Ann Arbor, Mich., served more or less as a clearance house in supplying the States with scientific information on the Great Lakes fisheries.

One important Great Lakes interstate conference should be referred to here. It was called at Chicago by the Director of the Conservation Department of Wisconsin on January 5, 1933, for the purpose of considering uniform regulations of the commercial fisheries of Lake Michigan. The meeting was attended by officials of the four States fronting Lake Michigan and of the Bureau. Excellent conservation measures were agreed upon at the conference, but these later failed of passage in the several States. In addition to this Chicago meeting, Dr. Van Oosten attended some 17 other conferences during 1933 largely in connection with fisheries legislation. He has also represented the Bureau at various meetings called for the purpose of drawing up a Great Lakes fishery code and has provided the basic conservation measures that are being considered for inclusion in this code.

FISHERY STATISTICS

In July 1933 the Bureau began an intensive statistical study of the commercial fisheries of the Great Lakes waters of the State of Michigan under the immediate supervision of Dr. Ralph Hile. Data in the form of monthly reports submitted by each licensed fisherman to the department of conservation furnished the material for the investigation. Each report contained a daily record of the catch by species, the kind and amount of gear lifted, the length of time the gear was fished, and the location of the fishing grounds. The reports for the years 1927 and 1928 were by no means complete, but since the beginning of 1929 there has been available a virtually complete record of all commercial fishing activities in the State.

For the purpose of analysis of the statistical data the Great Lakes waters of the State of Michigan have been divided into statistical districts which, as far as possible, represent natural geographical divisions. There are 7 districts in Lake Superior, 11 in Lake Michigan, 6 in Lake Huron, 1 in Lake St. Clair, and 1 in Lake Erie. The analyses have been directed toward a study of fluctuations in the total catch and total intensity of the fishery and also in the relative abundance of the several important species from year to year and from one locality to another. Abundance is calculated in terms of yield per unit of fishing effort.

The use of identical types of gear in totally unrelated fisheries and important variations both from one region to another and from one time of year to another in the amount of time gear is fished before it is lifted have made necessary the development of special methods of analysis for the study of Great Lakes fisheries statistics. The former difficulty was met by an allocation of effort in the direction in which it was actually exerted, that is, a particular unit of gear is considered to have fished for a given species only when some quantity of that species is included in its catch. The latter of the above mentioned difficulties was obviated through the introduction of the time element in the computation of fishing effort. Thus the fishing effort represented by a day's lift is not merely the amount of gear lifted, but rather is the product of the amount of gear lifted and the time the gear has fished. The sum of these separate products can be considered to represent the true fishing intensity for a given district or a given period of time. A detailed explanation and justification of these methods has appeared in a special publication.

At the present time the statistical studies are being confined chiefly to Lake Huron. In the near future a report will be prepared on the statistics of the commercial fisheries of that lake for the 5-year period, 1929–33.

PIKE-PERCHES

H. J. Deason was detailed to make a brief survey of the commercial lifts of trap nets operated during the period, April 3–14, 1933, in the vicinity of Sandusky, Ohio, and the islands of western Lake Erie. Particular emphasis was placed on the percentage of illegal saugers taken in these nets. Counts were made in the field of all legal and illegal saugers, yellow pike-perch, and yellow perch taken in 104 commercial trap nets operated at Sandusky, Put-in-Bay, and Toledo. Many saugers were also weighed, measured, and sexed at these three localities.

In addition much work has been done on the life history studies of the pike-perches of Lake Erie. A publication on these species was completed and presented at the annual session of the American Fisheries Society. It was observed that dominant age-groups occurred in the collections made in 1927 and 1928. The 1926 year class was dominant in both collections in the case of the yellow and blue pike-perch, and probably also of the sauger. Comparing the growth rate of the three species of pike-perches it was found that the yellow pike-perch ranks first in the rapidity of growth, sauger ranks second, and the blue pike third. The sauger, however, becomes sexually mature at a smaller size than does the blue pike-perch and the latter matures at a smaller size than does the yellow pike-perch.

A study of the relationship of percentage of immaturity to the existing legal size limits now in force in Lake Erie indicates that the present size limits of all three species of pike-perches should be increased to afford better protection to spawning females. In order to help insure spawning by females at least once, a size limit of 15 inches total length is indicated as a minimum for yellow pike-perch. On a similar basis, a minimum of 13½ inches total length is recommended for blue pike-perch and a minimum of 12½ inches total length for saugers.

A report was also completed on the analyses of the stomach contents of the yellow pike-perch, sauger, and grass pike from Lake Champlain.

YELLOW PERCH

Studies of the life history of the yellow perch of the Great Lakes were continued. Scales from 2,434 fish were examined during 1933. Of these 2,434 scale samples, 1,095 were collected from western Lake Erie in 1929, 1930, and 1932; 513 were collected from Green Bay in 1932; 606 were collected from Saginaw Bay in 1929 and 1930; and 220 were collected by the University of Michigan Museum of Zoology during different years. Growth rates have been calculated for all except the Saginaw Bay collections.

Although detailed comparisons have not been made as yet, the growth rate of the fish from Green Bay appears to be very similar to that found in Lake Erie. This conclusion refutes the argument of the Green Bay fishermen of Wisconsin that the perch in their waters are dwarfed in growth and that therefore a small size limit on this species in Wisconsin waters is justified and necessary. The Lake Erie collections of 1929, 1930, and 1932 when compared with the 1927–28 collections seem to show that the yellow perch has increased its growth rate somewhat after 1928. The yellow perch from Saginaw Bay appear to grow at a faster rate than those from Lake Erie or Green Bay.

To check the suspicion that more than one race of yellow perch inhabited Lake Erie, body depth measurements were compiled for 613 yellow perch collected off Lorain, Ohio, and for 114 yellow perch collected off Erie, Pa., both collections having been made in 1929. Slight differences in body depth were found between the sexes of a collection. The fish collected off Erie, Pa., were found to be somewhat slimmer bodied than those taken off Lorain, Ohio, but the difference was found to be so small that on the basis of these data it cannot be concluded that more than one race of perch exists in Lake Erie. Additional evidence will be sought in the comparative study of the growth rates of the yellow perch taken both from the western and eastern end of Lake Erie.

COOPERATIVE INVESTIGATIONS OF WISCONSIN LAKES

For many years the Bureau has cooperated with the Wisconsin Geological and Natural History Survey in limnological investigations of both fundamental and practical value on the lakes of northern Wisconsin. The Bureau's share in the cooperative enterprise consisted of modest financial support, the planning and technical supervision being provided by Drs. E. A. Birge and Chancey Juday of the State organization.

In 1933 the Wisconsin Geological and Natural History Survey received financial assistance for these cooperative investigations from the United States Bureau of Fisheries, Wisconsin Conservation Department, Alumni Research Foundation, and Thomas E. Brittingham, Jr.

The Survey's Trout Lake Laboratory was opened on July 1, and work was continued until September 9. The physical, chemical, and part of the biological investigations were discontinued on August 31, but the plankton and fish researches were continued into September.

The field party consisted of the following individuals: H. C. Baum, E. A. Birge, S. X. Cross, A. D. Hasler, R. Hunt, C. Juday, R. R. Langford, W. E. Militzer, E. Schneberger, H. A. Schomer, John Schreiner, W. A. Spoor, and L. R. Wilson. Dr. V. W. Meloche of the Department of Chemistry spent the greater part of July and August at the laboratory making a special study of some of the chemical problems involved in the investigations. Nine of the 14 members of the field party were working on problems which had a direct bearing on the fish life of the lakes. In addition to the field party, R. J. Allgeier was engaged in making analyses of lake residues in the chemical laboratory of the University of Wisconsin.

In the earlier years of these investigations, a general survey of the lakes of northeastern Wisconsin was made; it included one or more visits to some 530 different bodies of water. This survey was made for the purpose of obtaining some idea of the physical, chemical, and biological status of the lake waters of this district.

The general survey was completed in 1930 and since that time the investigations have been limited chiefly to six lakes representing the different types found in the district. These studies have had as their main objective the physical, chemical, and biological conditions for fish life in these lakes; the work on the fishes themselves has dealt with the kind and quantity of food eaten by the various species, the number and kinds of parasites harbored by them, and the rate of growth of the more common species in the different lakes. During the summer of 1933 another fish problem was added to these, namely, the determination of the total fish population of some of these lakes. Such information is necessary for a study of the fish production and of the fish-carrying capacity of a lake. It will also serve as a basis for experimental work relating to the increase of the carrying capacity of a lake by the use of artificial fertilizers. It will also have a bearing on the problem of stocking a lake with fish.

The details of the program and the results of the year's work are not presented here because of lack of space but may be consulted in the regular reports of the Survey and in the following publications:

BERE, RUBY.
Numbers of bacteria in inland lake waters of Wisconsin as shown by the direct microscopic method. Internat. Revue ges. Hydrobiol. and Hydrog. October.
JUDAY, C. and E. SCHNEBERGER.
Growth studies of game fish in Wisconsin waters. Second Report, April. (Mimeograph form).
JUDAY, C. and E. A. BIRGE.
The transparency, the color and the specific conductance of the lake waters of northeastern Wisconsin. The Wisconsin Academy of Sciences, Arts and Letters, vol. 28.
MELOCHE, V. W. and T. SETTERQUIST.
The determination of calcium in lake water and in lake water residues. The Wisconsin Academy of Sciences, Arts and Letters, vol. 28.
TITUS, LESLIE and V.W. MELOCHE.
A microextractor. Industrial and Engineering Chemistry.

OYSTER INVESTIGATIONS

During the year 1933, oyster investigations under the direction of Dr. Paul S. Galtsoff were continued in Massachusetts, Connecticut, North Carolina, Florida, Louisiana, and Washington. Investigation in Massachusetts and Connecticut, with headquarters at Milford, Conn., consisted in experimental studies on growth and fattening of oysters, and in observations on seasonal changes in the chemical composition of oyster meat. The United States Fisheries Laboratory at Beaufort, N.C., served as headquarters for oyster investigations in the South Atlantic States and Louisiana, where a series of surveys of oyster producing bottoms was made with the view of ascertaining their suitability for the cultivation of oysters. On the Pacific coast, investigations on cultivation of native oysters were carried out at Olympia, Wash. The work of the Bureau was greatly facilitated by the cooperation of the respective State authorities who supplied boats, labor, and laboratory facilities.

GROWTH AND FATTENING OF OYSTERS

Observations and experiments on growth and fattening of oysters were carried out at Milford, Conn., and at Woods Hole, Mass., by P. S. Galtsoff, R. O. Smith, and V. L. Loosanoff. The Connecticut Shellfish Commission continued its cooperation with the Bureau in this research work, assigning the State boat *Shellfish* to assist in field work and providing laboratory facilities at Milford. During the cold season, the State boat was in dock, but field observations were continued through the courtesy of the Connecticut Oyster Farms Co., which provided a suitable boat and assisted in collecting samples. Laboratory work during the winter was carried out at the Osborn Zoological Laboratory of Yale University.

The research facilities at Milford have been materially increased by a construction of two concrete tanks which permitted experimental studies on artificial feeding of oysters and conditions increasing the productivity of the sea water. As a supplement to these experiments, several planktonic organisms were cultivated in the laboratories at Woods Hole, Mass., and Yale University. The purpose of the experiments was twofold; first, to determine the conditions which accelerate propagation of marine algae, thereby increasing the food content of the water, and second, to determine the nutritive value of different forms in the oyster diet. Since the understanding of the natural sequence of seasonal changes taking place in the sea is prerequisite for a successful solution of these problems, observations were continued on changes in water temperature, chemical composition of sea water, plankton content, and growth and changes in the chemical compositions of oysters. Until the end of July 1933 samples were collected at three stations located in Long Island Sound. Since August 1, observations at 2 stations (lots 618 and 644) were discontinued, because oysters were moved by the owners of these lots to other locations.

The results of observations made at weekly intervals show that growth of the oyster continues throughout the year even when the organism is in a state of hibernation. During the year the average total weight of 4-year-old oysters, kept on experimental ground at Charles Island in Long Island Sound, increased from approximately 150 to 250 grams. The increase continued throughout the year, but there were two periods of accelerated rate of growth, one coinciding with the period of gonad formation in June–July, the second one occurring in October–November, at the time of the greatest accumulation of glycogen.

The weight of the oyster shell constitutes from 76 to 81 percent of the total weight of the organism, whereas the weight of its meat fluctuates between 8 and 13 percent. Spawning sharply reduces the weight of the meat from 13 to 8 percent of the total weight, but is immediately followed by a gradual recovery. The maximum weight of the meat was found to occur in November, just before the onset of hibernation. During the period of hibernation there is a gradual decrease in the relative weight of meat.

Simultaneously with the observations on oysters, samples of plankton and water were collected for biological and chemical analysis. Abundant material, accumulated in the course of the investigation, is now being analyzed.

PREDICTION OF SETTING IN LONG ISLAND SOUND

Observations on the development of the gonad, started in 1932, were continued in 1933. Samples of oysters, examined in May and June, showed that the amount of spawn to be discharged was far below normal. Oystermen were notified that poor setting was to be expected, and those who, upon receiving this advance information curtailed their planting operations, saved money because, true to our expectations, there was no setting in the largest section of Long Island Sound.

PROPAGATION OF DIATOMS FOR THE ARTIFICIAL FEEDING OF OYSTERS

Laboratory experiments on plankton as affected by various substances added to sea water were carried out by P. S. Galtsoff, R. O. Smith, V. Koehring, and V. L. Loosanoff. In the majority of the experiments, a pure culture of the small diatom, *Nitzchia closterium*, has been used, but attempts were made to isolate other forms which may be useful in artificial feeding of oysters. At present, the following microorganisms have been isolated and their cultures are being continued in the laboratory: *Nitzchia closterium*, Nitzchia sp. (very small diatom from California), Carteria sp. (green alga, family Chlamydomonadinae), Cromulina sp. (greenish alga, order Chrysomonadinae), and an extremely small, pink microorganism not yet identified. The latter form was isolated from the samples collected on oyster beds in Great South Bay, where oysters developed unusually dark pigmentation.

By using various combinations of inorganic salts and organic substances, a method has been perfected whereby very dense cultures of diatoms can be obtained. At present, the richest culture growing in the laboratory contains 1,400,000 diatoms in each cubic centimeter of water. Under proper light and temperature conditions, this dense population can be maintained almost indefinitely by withdrawing every day a portion of the culture and replacing it with an equal amount of solution. It is intended to apply this method in producing large quantities of diatom cultures and in using them for artificial feeding of oysters.

THE USE OF SLAG IN OYSTER CULTURE

A series of experiments was performed with slag, a byproduct of the steel industry, which has been recently brought to the attention of oyster culturists as a material suitable for cultch. Experiments carried out at Onset and Wareham River, Mass., showed that oyster larvae readily attach to the surface of slag and grow well. Its presence in water may increase the productivity of oyster beds, because slag has been found not only to promote the growth of diatoms, but to maintain it for longer periods than in the control cultures. The presence of slag on oyster beds is therefore of double advantage, serving as a source of nutriment to the oyster food as well as material for the attachment of spat.

The growth promoting factors of slag may be extracted by repeated boiling in sea water—diatoms growing rapidly in the filtrate. Untreated slag lumps as they are received from the mills are highly favorable to growth. Some of the growth-promoting factors of slag seem to be removable by alcohol washing, as growth in cultures containing alcohol-washed slag, while more prolonged than the growth in the controls, is not so rapid as in cultures containing untreated slag.

OYSTER PLANTING IN NORTH CAROLINA

In order to rehabilitate the depleted natural oyster beds of this State, transplantation of seed oysters has been carried out under the direction of Dr. H. F. Prytherch, in cooperation with the North Carolina Department of Conservation and the Civil Works Administration. These operations have been conducted in 5 coastal counties where during December 1933 a total planting of over 272,000 bushels of seed has been made at an average cost of aproximately 9 cents per bushel. In order to maintain production of the areas from which seed oysters have been obtained, large quantities of old oyster shells have been scattered over the bottoms to provide a place of attachment for subsequent generations of this shellfish. The planting of seed oysters and shells will be continued during 1934, with funds provided by the Civil Works Administration. Up to the present time, this work has provided employment for 266 of the oyster fishermen of this section. Experimental oyster farming operations conducted by the Bureau during previous seasons have served as a guide in the selection of suitable planting bottoms and in the adoption of the most practical and efficient methods for the rehabilitation and future maintenance of this valuable natural resource.

At the Beaufort laboratory an improved method of opening clams has been developed by Dr. V. Koehring and Dr. Herbert F. Prytherch. It has been found that clams may be easily opened by immersing them in a warm bath of fresh or sea water having a temperature of 105° F. In these experiments 100 percent of the clams opened their shells in from 10 to 20 minutes and when removed from the bath a few minutes later were completely narcotized. The meats could then be removed with comparative ease and were alive and in as fine condition as if they were opened raw. This process is suitable for either the raw trade or canning of hard clams and will be tested on a commercial scale in the near future.

OYSTER INVESTIGATIONS IN FLORIDA

During April and May, extensive oyster farming operations were conducted by Dr. H. F. Prytherch in the region from Panama City to Pensacola in cooperation with the Florida Department of Conservation. Previous studies made by the Bureau in Choctawhatchee Bay disclosed a scarcity of old shells or suitable objects to which the spawn of the oyster might attach, and indicated the necessity of planting shells and seed oysters in this area to create and extend natural beds and utilize the barren bottoms that are suitable for cultivation of this shellfish.

A survey was made of the principal oyster producing areas in the Pensacola region including East Bay, Blackwater Bay, and Escambia Bay. Excellent conditions for oyster propagation and the production of a high grade marketable product were found in East Bay and recommendations were offered for the development of this region by transplantation of seed oysters from the natural beds in Blackwater and Escambia Bays. In the vicinity of Panama City serious depletion of the natural beds in North Bay and East Bay was observed. Rehabilitation and future maintenance of these can be accomplished by regularly restocking them with seed and shell and by enforcement of the cull law. An adequate supply of seed for this purpose was found on the overcrowded oyster reefs in nearby waters such as West Bay.

Biological studies of oyster spawning and setting were made in all the previously mentioned waters which showed that shell planting operations should be carried out during April and May.

OIL POLLUTION INVESTIGATIONS IN LOUISIANA

At the request of the Louisiana Department of Conservation the Bureau has undertaken an investigation to determine the cause of the recent oyster mortality in Terrebonne Parish and its possible relation to oil-well pollution of these waters. Oyster planters operating in the vicinity of the oil wells in Lake Pelto and Lake Barre suffered a heavy loss of their stock during the winter of 1932–33 and to a lesser degree during the previous winter.

A preliminary survey of this region by Dr. Prytherch in May 1933 showed that 50 to 95 percent of the adult oysters on the planted beds, had died previously but no direct relation could be established between the degree of mortality on these areas and their distance from the oil wells. Pollution of the water by oil, brine effluent, and gas (H_2S) was greatest in the vicinity of the Lake Barre wells, and yet live oysters were found on the piling of these wells and on a natural bed in their immediate vicinity.

The problem is further complicated by the fact that the mortality was limited chiefly to the larger oysters and that the natural enemies, the boring sponge and boring clam, which heavily infested most of their shells, were apparently unaffected under the same conditions. A severe attack of these enemies lowers the vitality of the oyster and it is believed that such a condition was an important contributing factor in the mortality of many of these oysters.

On several beds, however, a high death rate occurred where there was no evidence of the boring sponge or clam. Fortunately it was possible to obtain samples of weak surviving oysters from these areas and others for miscroscopical studies, which have subsequently shown that the tissues of the muscle and gills were heavily infected with a minute protozoan parasite. Studies are being continued of the life history and occurrence of this protozoan parasite in Louisiana oysters and its possible relation to recent mortality.

EXPERIMENTAL STUDIES OF OIL-WELL POLLUTION

Since pollution of the waters of Terrebonne Parish was coincident with the oyster mortality, it was necessary that laboratory experiments be conducted to determine whether the different polluting substances, crude petroleum, brine water and hydrogen sulphide, are toxic to oysters and other marine animals and in what concentration. At the Beaufort Laboratory this work has been in progress since July and has shown that (1) oysters, clams, and numerous marine invertebrates will survive and grow in water covered with a heavy film of crude petroleum; (2) shellfish are not killed when fed on suspensions of these oils and show no cessation in growth of shell; (3) oysters survive when completely immersed in oil once each hour over a period of 6 weeks; and (4) oysters and clams will grow on mud and sand bottoms saturated with different grades of oil. These experiments are being continued.

The most serious pollution from the oil wells is apparently the brine water extracted from the petroleum. The effect of the different brines on feeding, growth, and shell movements of the oyster are being investigated. Though small amounts have been found to be nontoxic to larval, spat and adult oysters over a short period of time, general conclusions cannot be drawn until the effects over a prolonged period have been determined. Dilute solutions of brine of the same salinity, pH, and oxygen content as sea water were found to be toxic to oysters and produced death in from 6 to 10 days.

OYSTER INVESTIGATIONS IN WASHINGTON

Investigations on the spawning and setting of the native oyster of the Pacific coast were continued at Olympia, Wash., under the direction of Dr. A. E. Hopkins. Accurate records have been kept during 3 seasons of the 2 most important oyster-producing bays near Olympia, and in 1933 similar observations were made in 2 additional bays. The results already are being employed by oyster growers to assist in determining the correct time to plant cultch for the collection of seed. Owing to the short summer in 1933 the setting season was only about half as long as in the 2 years preceding. While in 1932 between 160 and 170 broods of larvae were produced per 100 adults, showing that most of them spawned twice, in 1933 only about 75 percent produced broods during the entire season. The number of larvae released in 1933 was less than half as great as in the previous year, thus limiting the possible catch of seed.

In Oyster Bay spawning started just after the middle of May, but the larvae did not begin to set until July 3. As in the last 2 years, definite periods of setting occurred, as shown by counts of spat caught on shells planted at frequent intervals. Although there is considerable variation in the results for the 3 seasons studied, it appears that there are characteristically, in this bay 2 distinct setting periods: The first, at the beginning of the season, and the second, about 5 to 6 weeks later. In addition, secondary periods may occur either between or after these two. Results from two other bays, Oakland Bay and Little Skookum, studied in 1933, agree closely with Oyster Bay in time of occurrence and relative intensity of the setting periods.

On the other hand, Mud Bay, which has been studied extensively, appears to be entirely different with respect to spawning and setting, although there is little difference in the temperature and salinity of the water. In 1933 there was only 1 setting period, beginning July 25 and continuing for about 3 weeks, after which no setting of any importance could be observed. This appears to represent the typical season in this bay, for it is usually unsatisfactory as a producer of seed.

The time required for setting of larvae after their release into the open water appears to vary considerably from year to year and in different bays. From the time of beginning of spawning until the first spat were found there was in Oyster Bay in 1932 a period of 39 days while in 1933 it was 47 days. In each year 4 days longer were required in Mud Bay. Presumably this time depends upon environmental factors as yet not thoroughly understood.

The occurrence of periods of setting appears not to depend primarily upon corresponding spawning but upon tidal cycles. Analysis of the records of setting in all of the bays studied shows that setting periods occur during runs of extreme tides. Preliminary experiments were made to determine what factors favorable to setting are controlled by the tidal cycles, but with inconclusive results.

Experiments on the effect of changes in salinity on the feeding activity of the Pacific oyster were continued. It was found that if the salinity is reduced from about 28 to about 15 per mille adaptation is extremely slow, requiring many days, while a change from a lower to a higher salinity permits recovery within a few hours. It is probable that adaptation to such a low salinity is not so complete that feeding may continue as rapidly as in the higher salinity. If placed in water of a salinity of about 10 per mille, feeding appears to cease completely, though the shell may remain open and shell growth continue. Specimens have been kept in this low salinity for as long as two weeks without any indication of adaptation of the feeding mechanism, and even after being returned to more favorable water recover only very slowly. It is thought that these results will throw considerable light upon the problem of locating oyster beds in places where the oysters will fatten properly.

INVESTIGATIONS ON AQUICULTURE

The investigations originally undertaken in connection with fish cultural operations at the hatcheries have been expanded recently to include field studies dealing with the many and diverse factors which affect fish in their natural environment. This is a logical expansion of the work, since it is obvious that the welfare of the fish after being liberated in natural waters is fully as important as the efficient operation of our hatcheries. It is evident that no matter how successful our hatchery operations may be, the success or failure of artificial propagation in terms of catchable fish is determined eventually by conditions in the streams or lakes in which the fish are planted.

The experimental hatcheries at Leetown, W.Va., and Pittsford, Vt., are fortunately situated to serve as headquarters for field investigations, since each is located in a region noted for its excellent fishing. Within a short distance of the Pittsford station in the heart of the Green Mountains, there are many famous trout streams, while both trout and bass waters are readily accessible from the Leetown station. Extension of these field studies will be greatly accelerated by an allotment from the Public Works Administration for stream surveys and stream improvement work during the summer of 1934.

In addition to the field work, investigations dealing with the various fish-cultural problems are being conducted as in the past. This work is conducted under the general direction of Dr. H. S. Davis.

POND-FISH CULTURE

Owing to drastic reduction in the Bureau's appropriations, all experimental work at the Fairport station was discontinued on July 1, 1933, when Dr. A. H. Wiebe, formerly in charge of this station, severed his connection with the Bureau. Consequently the only investigations during 1933 on the propagation and rearing of bass were carried on the Natchitoches (La.) station. These investigations were conducted by O. Lloyd Meehean and were a continuation of those carried on at the Tishomingo (Okla.) station during the summer of 1932. This transfer was deemed advisable on account of the better facilities for experimental work afforded by the Natchitoches station.

The experiments at Natchitoches afford the most clear-cut evidence of the influence of fertilization on fish production that has yet been obtained. The results show that both the number and size of the fish produced in a pond are directly proportional to the amount of fertilizer added. The results from 7 ponds, each with an area of approximately 0.85 acre, are available for comparison. Three of these ponds were fertilized with cottonseed meal at frequent intervals during the spring and early summer. A fourth pond received 1½ tons of cow manure at the beginning of the season. The other 3 ponds were unfertilized except for a small amount of cow manure early in the spring. The pond which received the largest amount of cottonseed meal (905 pounds) produced 12,245 fingerling bass per acre, which was the largest production obtained from any pond. A second pond, fertilized with 685 pounds of cottonseed meal, produced about 11,000 fingerlings per acre. The third pond received only 498 pounds of cottonseed meal and produced approximately 6,400 fish per acre. The pond which was heavily fertilized with cow manure early in the season produced only 2,941 fish per acre. The unfertilized ponds with one exception produced less than 3,500 fingerlings per acre.

The growth of the fish in the ponds fertilized with cottonseed meal was in direct proportion to the amount of fertilizer added. The pond which received the smallest amount of fertilizer produced the fewest and smallest fish. The pond fertilized most heavily and for a longer period than the others produced the largest fish and also the greatest number per acre. The fish from unfertilized ponds were not only fewer but smaller than those from fertilized ponds.

It is a noteworthy fact that the fish from the unfertilized ponds made much of their growth early in the season, since these fish were as large on May 24 as the others on July 25, just 2 months later. It is also of interest to find that fish in the fertilized ponds stopped growth shortly after fertilization was discontinued early in the summer.

As might be expected, a direct correlation was found between the number of food organisms in a pond and the amount of fertilization. It appears that the weed and bottom habitats are about equally important in the production of food organisms. This is of interest in connection with the control of aquatic plants in ponds.

Experiments with sodium arsenite were conducted to determine the relation of pH and alkalinity to the amount of the chemical to be used for the control and extermination of weeds in various waters. It was found that these are not the only factors affecting the results, since some other interfering substance is important in influencing the amount of sodium arsenite required. No information as to the nature of this substance has yet been obtained, but it is evidently something outside of those tested for regularly, since the difference in treatments could not be correlated with any of these.

It was also found that in order to make the sodium arsenite treatment effective it was first necessary to control the algae. This was best accomplished by a thorough mixing of copper sulphate in the surface water by agitation of the bag containing the chemical.

Investigations regarding the possibility of using fresh-water shrimp (Palaemonetes) as a forage food in bass ponds indicate that this will not be feasible under present conditions. These animals are not adapted to transfer from one habitat to another, while their small size makes them easy prey for the fish, resulting in almost total loss of brood stock. Shrimp are very sensitive to differences in pH and quickly die when transferred to waters showing a material difference in this respect from their original habitat. This is true even though the water may have an abundant supply of dissolved oxygen.

TROUT CULTURE

Feeding experiments.—As in 1932, feeding experiments were carried on at the Pittsford (Vt.) station under the direction of R. F. Lord and at the Leetown (W.Va.) station under the direction of E. W. Surber. Both brook and rainbow trout were used in these experiments. Several lots of Loch Leven fingerlings were also carried on experimental diets at the Leetown station.

Since previous experiments have demonstrated conclusively that better results can be obtained when certain dry products are included in the diet than by feeding fresh meats alone, the experiments in 1933 were primarily designed to determine the level at which these dry products can be fed most efficiently and economically. Unfortunately, owning to the limited funds available for experimental work, it was necessary to discontinue the experiments at both stations early in September.

As has been emphasized in previous reports, there is no dry product available commercially which can be fed to trout successfully for any considerable length of time without the inclusion of raw meat in the diet. With large fingerlings and older trout only 15 to 25 percent of raw meat is required to keep the fish in healthy condition. Unfortunately, mixtures containing such a small percentage of meat cannot be fed without considerable waste and it is consequently more economical to include a larger amount of raw meat than is necessary for the well being of the fish. The meat not only makes the ration more palatable to the fish but serves as a binder to hold the fine particles of meal together so they can be eaten readily. When the proportion of the meat is too small, the mixture quickly disintegrates in the water and much of the dry food is lost.

As in previous years, salmon-egg meal gave the best results of any dry product used, although, with regard to growth, there was very little difference between this product when used alone and a mixture of equal parts salmon-egg meal and a good grade of meat meal. Meat meal alone was somewhat inferior to salmon-egg meal.

The results of the experiments show that as high as 60 percent of dry meal may be economically incorporated in the diet. For instance, one lot of yearling rainbow trout, on a diet composed of 60 percent salmon-egg meal and 40 percent raw pig liver, gained 153 percent in weight from June 7 to September 1, while a second lot, on a diet composed of equal parts pig liver and salmon eggs, showed an increase of only 143 percent during the same period. The conversion factor was slightly better when the larger amount of salmon-egg meal was used, since it required 2.1 pounds of food to produce a pound of trout when this product was fed at a 50 percent level, and only 1.9 pounds when fed at a 60 percent level. When the dry constituent of the diet is still further increased, the mixture disintegrates so readily that it is very difficult to feed without considerable waste.

Since it is a universal practice to feed rapidly growing fish all they will eat, experiments were run at both the Pittsford and Leetown stations to determine if a reduction in the amount of food would result in its being utilized more efficiently. The results are inconclusive, although indicating that probably a somewhat greater efficiency can be obtained by feeding slightly less than the fish will consume readily. In the case of brook trout fingerlings, 2.4 pounds of food were required to produce a pound of fish on a diet of beef liver and salmon-egg meal when the fish were fed all they would eat readily. In another lot of trout on the same diet but given 25 percent less food than the former lot, 2.3 pounds of food were required for each pound of fish produced. Rainbow fingerlings made a better showing, since the amount of food required to produce a pound of fish was 2.8 and 2.1, respectively. In the case of brook fingerlings at the Leetown station on a similar diet, 2.57 pounds of food were required for each pound of fish produced, when the fish were given all they would eat, and 2.67 pounds when fed 25 percent less. The rainbow fingerlings again made a much better showing. In this case 2.58 pounds of food were required for each pound of fish produced when the fish were fed all they would eat, while only 2 pounds were required when the amount of food was reduced 25 percent.

With rainbow yearlings at the Pittsford station, a reduction of 10 percent in the amount of food in the case of fish fed a mixture of equal parts of pig liver and salmon-egg meal, resulted in 1.8 pounds of food to 1 pound of trout as compared with 1.9 pounds in fish fed the larger amount. When fed pig liver a considerably larger amount of food was required to produce a pound of fish, when the amount was reduced 15 percent, 10.6 pounds being required when the fish were fed the full amount and 13.7 pounds on the reduced diet.

It is scarcely necessary to point out that the growth on the reduced diets was considerably less in every case than that of fish fed all they would readily consume. It should be emphasized, however, that in no case were the fish overfed. The fingerlings were given only as much food as they would readily eat twice a day, while the yearling trout were fed only once a day.

In an effort to clear up some of the uncertainty regarding the amount of food required to support trout in nature, a number of brook and rainbow trout fingerlings at the Leetown hatchery were kept on natural food from May 3 to October 12. The food of these fish consisted principally of the water sawbug (Asellus) with some gammarus and a few snails. A supply of these organisms was kept in the troughs at all times so that the fish had all they could eat.

Within 3 weeks after the experiment was started, the color of these fish was noticeably brighter and within a short time they became the most highly colored fish at the station, in fact, the colors were much more intense than those of the average wild trout.

At the end of the experiment the average individual weight of the brook trout was 33 grams and of the rainbow trout 34.5 grams.

It was found that in the case of brook trout 6.9 pounds of food were required to produce a pound of fish, while with the rainbow trout 7.4 pounds were required to produce the same amount. On a dry basis it required approximately 1.86 pounds of food to produce 1 pound of fish in the case of the brook trout and 2.05 pounds in the case of the rainbow. The less efficient use of food by the rainbow trout may possibly be caused by the greater activity of this species.

Selective breeding.—Experiments in selective breeding of brook trout were continued at the Pittsford station along much the same lines as in previous years. As pointed out in some detail in the report for 1932, rigid selection for two generations has resulted in a notable increase in rate of growth and egg production. In fact, the improvement in these respects has been much greater than it was thought could possibly be accomplished in such a brief time. In view of the success of these experiments at Pittsford, the same methods of selective breeding are being extended to rainbow and brown trout at the Leetown station. This is the first season trout have spawned at this station, the oldest fish being only 2 years old.

In order to obtain a fair comparison of the growth of selected and nonselected fish, three lots of brook trout fingerlings were reared at the Leetown station under as nearly identical conditions as possible with respect to food and water supply. Each lot, containing 1,200 fingerlings, was placed in a standard hatchery trough on March 1, where the fish remained until the experiment was discontinued. Two lots of fish were from eggs taken at the York Pond (N.H.) station. One lot of these eggs was from fish which had been reared from wild trout; the second lot from fish still farther removed from the original wild stock. The third lot of eggs was taken from selected stock at the Pittsford station.

From the beginning of the experiment the fish from the Pittsford station grew more rapidly than those from the York Pond station. There was practically no difference in the growth of these two lots of fish. The experiment was discontinued in August when the fish in each lot were 29.5 weeks old. At this time the average individual weight of the Pittsford fish was 11.5 grams. The weight of one lot of York Pond fish was 4.9 grams and the other lot 4.6 grams. There was also a marked difference in mortality, which in one lot of York Pond fish totalled 718 and in the other 546. The loss among the Pittsford fish was only 169 during the same period. The mortality in all three lots was abnormal, but no attempt was made to correct it by treatment of any kind. The higher mortality among the York Pond fish should have given them the advantage with respect to growth so the fact that the Pittsford fish grew almost twice as fast is all the more notable.

Hatchery techinque.—In an effort to determine the number of young trout which can be handled most economically in hatchery troughs, four troughs at the Leetown station were stocked with rainbow fingerlings as follows: Trough no. 1 received 500 fish; trough no. 2, 1.000 fish; trough no. 3, 2,000 fish, and trough no. 4, 3,000 fish. These fish were all from the same lot, with an average weight of approximately 1 gram at the beginning of the experiment. All 4 lots of fish grew at about the same rate until April 26 when the fish in no. 4 trough were found to weigh approximately 0.3 gram less than those in the other troughs. From this time on the slower growth of the larger lots became more and more noticeable, until on July 10 it was necessary to discontinue the lot in trough no. 4 on account of an outbreak of bacterial gill disease.

The average individual weight of the fish in each lot on July 5 was as follows: Trough no. 1, 14.26 grams; no. 2, 13.27 grams; no. 3, 11.15 grams; and no. 4, 8.89 grams. The mortality up to the time of the outbreak of the gill disease in trough no. 4 was in all cases too small to be of any significance. The results show clearly that overcrowding not only retards the growth of the fish but also increases their susceptibility to disease.

A series of experiments were carried out at the Leetown hatchery to determine the amount of oxygen removed from the water in troughs containing various numbers and sizes of fingerling trout. The complete results cannot be given here, but a few examples may be of interest. The troughs were supplied with water having a temperature of 54° F. at the rate of 5.17 gallons per minute. In one trough containing 1,500 brook trout with an average individual weight of 13.45 grams, 5.78 parts per million of oxygen or 60.02 percent of the total amount in the water was removed by the fish. In another trough containing 20,461 rainbow fingerlings with an average individual weight of 0.24 grams, the amount of oxygen removed was only 1.4 parts per million or 12.5 percent of the total amount. In a third experiment 3,900 black spotted trout fingerlings, averaging 2.33 grams in weight, removed 1.88 parts per million of oxygen, or 18.02 percent of the total amount present.

Feeding greatly increased the consumption of oxygen, as shown in the case of a trough containing 1,500 brook trout, with an average weight of 13.45 grams. On the morning of November 28 after these fish were fed 300 grams of food, 7.26 parts per million of oxygen were consumed in this trough. At 4:05 p.m., several hours after feeding, the consumption of oxygen in the same trough was only 4.72 parts per million, or 44.74 percent. At this time the fish were again given 300 grams of food, and the oxygen consumption rose to 8.55 parts per million, or 81.04 percent of the total amount present. It is evident from these experiments that in overcrowded troughs there is a distinct possibility that during or shortly after feeding the oxygen content of the water may drop to dangerously low levels even though at other times the supply may be more than sufficient for the needs of the fish.

A self-cleaning device for use in circular pools has been developed by Mr. Surber, which it is believed will greatly simplify the operation of this type of pool. The device consists of a large sleeve, which is attached to the outlet pipe and extends for a short distance above the surface of the water. At the bottom there is a small opening between the sleeve and a sloping flange which rests on the bottom of the pool. The width of this opening can be easily adjusted according to the size of fish in the pool. Excrement and waste material are drawn through the opening by the water flowing through the outlet pipe, thus automatically keeping the pool clean and in good sanitary condition.

Field studies.—A quantitative study of rainbow trout production in a small spring-fed stream near Leesburg, Va., was made by Mr. Surber. This stream has been turned over to the Bureau by the owner for experimental purposes, and all fishing except by authorized persons is prohibited. Trout are prevented from leaving the stream by a revolving screen at the lower end. However, owing to severe floods, the operation of the screen during the fall and winter of 1932–33 was so spasmodic that it is believed that the screen had little effect in retaining the fish.

A total of 49 pounds of fish, over 7 inches long, were removed from the stream during the season, or an average annual production of approximately 30 pounds per acre. It is known that a number of large trout were left in the stream so that the total production was undoubtedly somewhat greater. A study of the stomach contents of these fish shows that although amphipods and aquatic insects were abundant, the trout during the summer fed almost entirely upon terrestrial insects.

In connection with the field work at the Pittsford station, an arrangement was made with the Middlebury College, Middlebury, Vt., for the development of a program for improving trout fishing in the streams under the control of the college. Most of these streams are in the Battell Forest, a beautiful tract of over 30,000 acres, located on both slopes of the Green Mountains. Owing to the limited funds and personnel available for this work during the summer of 1933 it was only possible to make a preliminary investigation of the more important streams in the forest. A more complete study of the streams to be followed by a systematic program of stream improvement will be undertaken in 1934.

During the summer of 1932 a number of marked yearling brook trout were liberated in an excellent trout stream adjoining the hatchery grounds at Pittsford to determine if domesticated fish could care for themselves under natural conditions as well as wild fish and also if they would afford equal sport to the angler. The results were of such interest and value as to suggest the advisability of conducting a similar experiment with rainbow trout. Accordingly, on September 3, 1933, 100 marked yearling rainbow trout were set free in the same section of the stream in which brook trout had been liberated the previous year.

Observations made on these fish shortly after they had been liberated showed a much greater tendency to scatter than in the case of the brook trout. They were also more difficult to take on fly and on only 1 day during the course of the experiment was it found possible to capture the desired daily quota of 10 fish. Fishing was continued with varying intensity up to September 26. During this period the total number of marked fish taken was only 49, and in order to capture this number it was found necessary to resort to bait in a number of instances.

In general the rainbow trout reacted quite differently from the brook trout in the previous experiment. Especially noteworthy was the much greater tendency to move downstream with the current. For example, 59 percent of the fish recaptured were taken below the pools in which they had been liberated; 29 percent from the pools themselves; and only 13 percent had moved upstream from the point of liberation. On the other hand, in the case of the brook trout, 61 percent were taken upstream from the pools where liberated; 23 percent from the pools themselves; and only 16 percent had moved downstream.

Complete observations on this experiment will not be available until after the freshets in the spring of 1934, but it has already shown conclusively that hatchery reared rainbows, as well as brook trout, are fully able to care for themselves when thrown on their own resources.

California trout investigations.—The investigations of problems relating to the trout of California were carried on with the same personnel as in 1932. As a result of experience gained during the past year, it has been decided to modify in several important respects the program originally adopted for the investigations. Briefly the program as now developed calls for intensive work on two major projects with additional work on several minor projects, which will be carried on as time permits. One of the major projects which is concerned with trout problems relating to Sierran lakes and streams is under the immediate supervision of Dr. P. R. Needham, who is also in charge of the California investigations as a whole. The other major project is under the immediate direction of A. C. Taft and deals primarily with problems relating to sea-run steelheads. This project includes extensive studies in several coastal streams with especial attention to the Klamath River.

The minor projects include the planting of large numbers of marked trout in the Truckee River and Angora Lake, experiments in developing selected strains of California trout at the Hot Creek rearing ponds in Mono County, and the development of a stocking policy for water reservoirs near San Diego.

Work on environmental conditions in trout streams carried on during the past year has brought to light a number of new and interesting facts. Seasonal food studies made in Waddell Creek near Santa Cruz in August, November, March, and May, give a yearly average of approximately 198 pounds of insect food per acre of riffle area. Pools produced only 54 pounds per acre. On the other hand, Waddell Creek Lagoon averaged over 250 pounds per acre. While this stream produces principally insect food above the brackish water area, lagoon foods consisted almost entirely of crustaceans, of which 2 amphipods, *Gammarus confervicolis*, and *Corophium spinicorne*, and 1 isopod, *Exosphaeroma oregonensis*, offer abundant food to young salmonoids. In numbers, an average of over 10,000 crustaceans were found per square meter in the lagoon bottom, while the riffles in the stream above averaged only about 6,500 organisms to the same area.

In the Feather and Merced Rivers about the same amount of food was found to be present in winter as in summer, slightly more being present in winter. Streams in northern California, both coastal and Sierran, were found to be much richer in food than Sierran and coastal streams in the central and southern parts of the State.

The steelhead studies started at Waddell and Scott Creeks in 1931 have been continued. These two streams which are small in size and very similar in physical characteristics offer particularly favorable conditions for experimental work. One stream, Scott Creek, has been closed for years by an impassable dam near its mouth where all ascending steelhead are trapped and spawned. During the past summer a dam was constructed on Waddell Creek which will automatically trap all adult fish migrating upstream and will also capture a portion of the downstream migrants. In this stream the adult fish, after being measured and tagged, will be allowed to proceed upstream and spawn naturally. It is hoped in this way to obtain, among other things, accurate data on the comparative efficiency of natural and artificial propagation.

During the period January to May 1933, 82 adult steelhead trout of the 614 tagged the previous year returned to the station on Scott Creek. . These fish had been tagged on the gill cover with a no. 3 strap tag. Of these 82 fish 61 percent returned carrying the tag, and the balance were recognized by the hole in the abraded area where the lost tag had been attached. During the same period 368 fish were tagged after spawning, including the fish previously tagged. On these fish the celluloid disk tag attached by a nickel wire just below the base of the adipose fin was used. In addition to the work on the adults, 11,000 yearling fish were marked and planted in the lagoon.

Some field work was done on the Klamath River during the summer, and arrangements were made to hold fish in the Fall Creek hatchery for marking experiments during the coming spring. It is planned to expand the work on the Klamath considerably during the coming year.

FISH DISEASES

Studies of the bass tapeworm at the Fairport (Iowa) station, started in the summer of 1932 by Dr. Frederic F. Fish, were continued during the spring of 1933. These investigations show that this tapeworm has not caused serious injury to the bass at Fairport.

A detailed study of the causes underlying the heavy loss of bass fry in the nursery ponds indicated that protozoan parasites, particularly Cyclochaetea, are largely instrumental in causing such losses, and it was concluded that as a routine practice all fish should be dipped in a salt solution before they are placed in ponds. It was also found that smaller quantities of fry should be handled during the process of counting and weighing than has been the practice in the past.

Later in the season Dr. Fish made an investigation of a trout disease at the Cortland (N.Y.) station which caused a heavy loss among the fingerling trout. The disease is characterized by external lesions not unlike those of furunculosis and consequently has apparently been confused with it. However, detailed studies of the pathology of the disease show very clearly that it is quite distinct from furunculosis. Like furunculosis, it is highly pathogenic to many species of trout and has apparently caused serious losses at several hatcheries in New York State. The disease is evidently of bacterial origin, and several species of these organisms were isolated from the tissues. Although one of the organisms isolated from diseased fish is pathogenic to trout, it has not yet been demonstrated that it is the primary cause of the disease.

One of the greatest objections to the use of rearing ponds for trout fingerlings is the difficulty of treating the fish should they develop an external infection, such as gill disease. Removal of the fish and dipping by the methods now in general use is a laborious process and also results in many fish being severely injured by handling.

A method of treating fish in pools by allowing a chemical solution to flow into the pools at a uniform rate has been developed by Dr. Fish. The essential part of the device is a floating siphon, the proper concentration of the chemical in the pool being obtained by adjusting the strength of the original solution to the volume of flow. This is a very simple device and can be readily adapted to almost any type of pool. In this method the fish are treated for a considerable length of time with a very weak solution, which at the concentrations ordinarily used in the so-called "dipping method", would prove fatal in a few minutes.

A very efficient cure for bacterial gill disease has been developed at the Leetown station by Eugene W. Surber. This consists of treating the fish with chlorine gas dissolved in water at a concentration of 1 to 2.5 parts per million. Since this solution is quickly fatal to fish, the chlorine must be neutralized by the addition of sodium thiosulphate after 1.5 to 2 minutes. This treatment has been used with great success in circular pools and also in hatchery troughs. It has not yet been tried in other types of pools, but there appears to be no reason why it could not be successfully used wherever there is a rapid circulation of water.

COOPERATIVE STUDIES OF THE NUTRITIONAL REQUIREMENTS OF TROUT

Investigation of the problems connected with the feeding of trout in hatcheries, which were begun during the summer of 1932, have been continued during 1933 by Dr. C. M. McCay and A. V. Tunison at the Bureau's fish cultural station near Cortland, N.Y. This is a cooperative project conducted under an agreement between the U.S. Bureau of Fisheries, the New York Conservation Department, and the New York College of Agriculture at Cornell University. Special attention has been given to the nutritional problems as well as to the actual feeding experiments, in order to extend our knowledge of the principles of trout feeding beyond that obtained from the Bureau's older experiments of a practical nature in the same field. During the year the hatchery equipment has been altered and improved and electric power is now available. The latter is of considerable importance, since it provides means of controlling the physical environment of the fish that is essential in certain experiments and reflects the general tendency in all nutrition laboratories toward a better appreciation of the importance of such control.

While the work of the investigators was confined as far as possible to the field of nutrition, attention was given to the prevention of disease. Deficient diets inevitably lead to disease which may manifest itself as a distinct alteration in the anatomy and physiology of the trout, or may result in a secondary invasion of the sick fish by parasites; all of which tends to confuse the results obtained from experiments in nutrition. Moreover, the cure of disease may often lie in the hands of the nutrition student. Hence, the practice has been followed of treating the trout in the Cortland hatchery at weekly intervals, thus preventing to a large degree epidemics that otherwise would interfere with the experiments. Care has also been exercised to prevent the introduction of disease by importations of trout or eggs from various sources during the year. Moreover, in order to avoid the needless complication of iodine deficiencies in experimental diets, the practice has been followed of including in the rations each day from 0.1 to 0.2 milligram of potassium iodide per kilogram of live trout.

The major activities of the station were concerned with numerous experiments in three general categories: (1) Experimental feeding tests to determine the utility and value of various dry foods of animal and vegetable origin used as supplements to the regular meat diets and the reactions of various species of trout to these foods; (2) studies to determine the efficiency of conversion of commercial feed combinations in trout; and (3) studies concerned with the vitamin and mineral requirements of trout. No attempt will be made to present in detail the findings of these investigations for the information is being assembled for publication elsewhere, but only the general character of the work and the more striking results attained will be indicated.

During the previous season experiments were started to determine the relative growth of trout species on diets of meat and dried milk products. These experiments were run to compare the relative merits of dry buttermilk and dry skim milk when fed with equal parts of cottonseed meal and fresh meat, to compare the relative merits of spleen, heart, and liver as supplements for a mixture of dry buttermilk and cottonseed meal, and to compare the growth rates of rainbow, brook, and brown trout fed the same diet and surrounded by the same physical conditions. These experiments were undertaken again using fish of the same size which were placed upon experimental diets within a short time after the first feeding. Some of these experiments ran for 20 weeks and others for 60 weeks. Growth curves representing the mean of 400 individuals during the first 16 weeks and 200 individuals thereafter indicate that spleen and heart during such a period are as satisfactory as liver in supplementing cottonseed meal and dry skim milk. The dry buttermilk and dry skim milk proved of equal value for growth, although the latter is a better binder for dry feeds.

Using a diet of cottonseed meal, dry skim milk, and fresh meat (raw sheep plucks) in equal parts it was found that for 24 weeks brown trout grew more slowly than brook trout. An improved experiment using a more suitable diet for fry, which consisted of a mixture of fresh beef liver, 2 parts, and dry skim milk, 1 part, and using 500 fry for each experiment was continued for 40 weeks. The four species—brook, rainbow, lake, and brown trout—were used. Growth curves based on dry weight for the smaller sizes and live weight for the larger fish indicate virtually parallel growth rates for all species, although the brown trout during the latter weeks showed a somewhat reduced growth.

Beginning with their first feeding 425 fry were fed various diets for 24 weeks and the growth rates determined on both the dry weight and the fresh live weight basis. A diet of fresh beef liver and dry skim milk, 2:1, was used to determine if two daily feedings of such a diet were satisfactory. Although the growth curve showed good results, it was below the maximum. A diet of fresh beef liver and dry skim milk, 1:2, was fed 6 times daily as a basis of comparison for the growth rate obtained from feeding fresh beef liver and dry whole milk, 1:2. This experiment with whole milk was included to see if butter fat, which is present in the whole milk but very low in the skim milk, might not be advantageous in feeding young trout. This butter fat provides a diet richer in calories as well as the fat soluble vitamin A. In this combination, however, liver seems to provide adequate supplies of this vitamin, since the growth curves in the two experiments were identical.

At the same time another lot of trout was fed dry skim milk and raw egg in the ratio of 1:1 to test eggs as a source of the growth factor H, which is destroyed in the usual drying of fresh meats. No appreciable difference in growth rates was observed. Another diet consisted of dry skim milk, cottonseed meal, and white-fish meal in the ratios 2:1:1, fed regularly with a change to the diet of dry skim milk and fresh beef liver once a week. A slow growth rate from this diet was observed for the first 3 months, but after that the curves ran parallel with those obtained from better diets. The spray process of dry skim milk 92 percent, and vacuum dried beef liver 8 percent, was combined for the diet of another experimental lot. The liver was dried under 80° C. in an atmosphere of nitrogen. It was then stored under carbon dioxide until ready for use, in order to determine whether factor H found in fresh liver could be preserved in this way. For the first 20 weeks these fry grew very rapidly, but at the time they were approaching a mean weight of 2 grams their growth became very slow and they started dying rapidly. These experiments show that fry can pass through the early stages with excellent growth upon a dry diet, but even with the careful treatment it received the liver seemed to have lost much of its factor H.

In experiments started during the previous year growth curves were constructed for trout fed upon mixtures of dry buttermilk, skim milk, cottonseed meal, and peanut meal. Data were then available only for 16 weeks, but these groups of trout were continued for 8 additional weeks or a total of 24 weeks. Five hundred brook trout were used in each group at the beginning. At the end of 16 weeks this number was reduced to 300 in order to prevent crowding in the troughs. As far as these growth curves indicate these practical diets are equal in value. Either peanut meal or cottonseed meal are suitable trout feeds if combined with a binder such as dry skim milk. The percent utilization of such feeds, however, cannot be determined until balance experiments can be run.

During the past year standard fish hatchery troughs were used for running another series of studies upon commercial feedstuffs that had already been tested in previous years. Experimental diets were composed of varying proportions of dried skim milk, cottonseed meal, white-fish meal, salmon-egg meal, and raw beef liver. Each experimental group was started with 1,250 fingerling brook trout of the Pittsford (Vt.) strain and continued for 28 weeks.

The poorest growth was made by a group fed on a diet of beef liver alone. The best growth was obtained from the group fed on a diet composed of equal parts of cottonseed meal, skim milk, and salmon-egg meal, supplemented with 15 percent of fresh liver. White-fish meal can be substituted for the cottonseed meal and will produce similar results, both as regards growth and economy. Since the best growth resulted from the diet containing 15 percent fresh beef liver, this combination seems adequate for a period of at least 6 months.

In analyzing the results of these experiments with commercial feed combinations, the efficiency of conversion has been calculated to show the number of grams of feed required to produce 1 gram gain in weight of trout during the 4-month period, and also the cost of feed required to produce 1 pound of trout. It is furthermore of interest to compare the ability of different trout species to convert feedstuffs to body tissues, especially where there is a constant water temperature.

Analysis of the results shows that the dry feed required to produce 1 unit by weight of trout ranged from an average of 2.69 units, using a diet of skim milk, cottonseed meal, and raw beef liver, 1:1:2, to as high as 5.35 units, on a diet of skim milk, 29 percent; cottonseed meal, 28 percent; raw beef liver, 15 percent; and white-fish meal, 28 percent. The trout are somewhat more efficient than these figures show, however, because the losses of feedstuffs in the water are calculated as feed consumed.

In these studies the mean value for food conversion among the different species of trout are: Lake, 3.06; rainbow, 3.47; brook, 4.73; and brown, 5.14. These results to date indicate that the species that is most efficient food conversion in water with a temperature of about 47° F. is the lake trout, while the least efficient is the brown trout.

Experiments were undertaken to develop a biological method of assaying the potency of various growth factors in prepared food materials. In vitamin assay experiments with rats, it is a common practice to deplete their stores of a given vitamin until they cease to grow. At this point the substance to be assayed for its vitamin potency is fed at various levels to the animals that have been depleted. The growth response serves to measure the potency of the vitamin preparation. Attempts were made to establish such assay methods with trout, but thus far no standard procedure has been developed. We have no knowledge of the relative requirements of fish for vitamins compared to the higher animals.

Two lots of experimental fish, which showed the usual marks of failure upon totally dried diets, were changed to a diet of dry skim milk, supplemented with fresh liver, preserved in 5 percent by weight of calcium hypochlorite. Upon this new diet the growth rate became normal and the mortality rate declined, indicating that trout can ingest meat preserved in hypochlorite without apparent injury.

Another lot fed on a dry diet until the growth rate had fallen and mortality sharply increased was transferred to a diet of dried skim milk, supplemented with one-twentieth of its weight of liver dried in a current of nitrogen. The growth and mortality curves confirm earlier findings that liver will retain some of its potency in factor H if dried at a low temperature in inert gas. Such experiments represent relatively crude assays but they provide the foundation for improved ones.

After the first experiments with trout feeding, a requirement for specific substances similar to vitamins was recognized by Dr. McCay. This vitamin requirement could not be stated in terms of recognized accessory factors since it was very sensitive to heating and was destroyed when food products were dried at the usual high temperatures in contact with air.

In the course of the past 3 years, it has been discovered that this vitamin termed factor H is partially preserved by drying at low temperatures in contact with an inert gas. Since the determination of the requirements of trout for the recognized vitamins is very difficult until more is learned concerning the nature of factor H, efforts have been continued to prepare a concentrated extract containing this growth factor.

Two methods of testing have been employed. One consists in feeding trout on a purified mixture of casein, a starch-dextrin, yeast, cod-liver oil, and salt mixture, plus the supplement to supply factor H. Yeast and cod-liver oil have been used simply because it is very likely that all higher animals require some of the factors contained in yeast as well as some of the fat soluble vitamins.

Up to the present time only alcoholic extracts of beef lungs and liver have been prepared. Careful methods have been employed in order to preserve the accessory growth factor. Dried beef liver, evaporated in vacue under inert gas, was prepared as a control.

From a number of assays it was found that 15 percent of raw liver was an adequate supplement for an otherwise complete diet, furnishing a sufficient supply of factor H. Hence, the present experiments were started with a 5 percent supplement on concentrated products, but growth and mortality curves show that this level was too low. At the end of about 2 months the supplement was increased to 15 percent. Nevertheless, growth curves indicate that much of the original growth factor was lost even in the vacuum dried liver. It also indicated that a considerable fraction of factor H is held in the alcoholic extract. The lung residue is almost totally lacking in this factor, while the liver residue still retains some potency.

A second series of assays were undertaken, testing the efficiency of autolyzed liver products as supplements for a synthetic diet deficient in factor H, in the hopes of finding a liquid liver with a high degree of potency. These data indicate that raw egg and liver extract, plus residue, have considerable amounts of factor H, but they do not clearly establish that autolysis destroys factor H because the material used as a preservative in the course of autolysis may have influenced the results.

LIMNOLOGICAL INVESTIGATIONS IN THE ROCKY MOUNTAIN REGION IN THE INTEREST OF FISH STOCKING

Because of the severe curtailment of the Bureau's appropriations, investigations in the national parks and forests under the direction of Dr. A. S. Hazzard were omitted during 1933, and a program of field work which entailed minor expenditures was substituted. However, lessened field activities afforded opportunity for study of data previously obtained and made possible the preparation of several papers for publication.

QUANTITATIVE FOOD STUDIES IN MOUNTAIN STREAMS

Numerous samples of bottom organisms were taken from square-foot units of bottom in four mountain trout streams in the vicinity of Salt Lake City, using methods developed by Dr. Needham, of the Bureau's staff. The purpose of these studies was threefold: to determine the variation in food supply at different elevations in the same stream and in different streams; to study the fluctuation in numbers and weight of bottom organisms in three streams during the months of July, August, and September; and to secure some information as to the relative productivity of trout streams in this region as compared with those studied in other parts of the country.

Fifty-three square-foot samples, taken in the riffle areas where the bottom consisted of gravel and small rubble, showed great variation both as to numbers and total weight of organisms in different streams. Since other environmental conditions were similar, higher temperature was considered responsible in certain waters for the production of greater variety and quantity of food. Caddis flies and may flies were found to be dominant organisms in these mountain streams.

Samples taken at elevations from 4,400 to 7,500 feet on one stream and from 5,700 to 7,000 feet on another showed no appreciable difference in weight over the average for each stream.

The studies also indicated that the food supply for any stream is not constant for the summer months. In one stream a rise in weight of samples occurred in August, followed by a decline nearly to the July level in September. In another an increase in weight was noted throughout the summer. In the third, a marked decrease in the average weight of samples occurred in each successive month. On the other hand, all three streams showed a marked increase in the number of organisms in August, followed by a decrease in September, which, however, did not reach the July level. This indicates that August is probably the best month for planting small trout in our mountain streams as the smaller organisms are most numerous then.

The average wet weight of the 53 samples was found to be 1.18 grams, although the average for the 3 streams studied monthly was 1.69. These averages compare very closely with those for trout streams of New York and California having a similar type of bottom.

The results of this investigation were presented at the fall meeting of the Utah Academy of Sciences and will appear in abstract form in the proceedings of this society for 1933.

COOPERATIVE INVESTIGATIONS

Through the cooperation of the Utah Fish and Game Department in defraying field expenses and furnishing assistance, limnological studies were made of three important fishing waters for the purpose of developing better plans for regulation and planting. The Division of Fish Culture of the Bureau also made possible a study of Bear Lake, Utah.

Fish Lake.—Inasmuch as this is probably the most productive trout lake for its size in the country, the privilege of making a limnological study here was welcomed not only as an opportunity to assist the State in its planting policies there, but also to seek to determine the reason for its phenomenal productivity. Since accurate information as to what constitutes a good trout lake is scarce, additional information is of great value in judging the carrying capacity of other waters and in seeking means to improve them.

The usual procedure for the study of lakes was followed except that more complete data were taken than is usually possible during a preliminary survey. One hundred forty soundings were made as a basis for the construction of a reasonably accurate contour map. Temperatures were taken at frequent intervals from surface to bottom in various parts of the lake. Chemical analyses for dissolved oxygen, free carbon dioxide, carbonates, bicarbonates and pH were made at a number of stations and on the principal tributaries. Transparency was measured by the Secchi disk. Numerous samples of plankton and bottom foods in the benthic and littoral zones were secured. The type of bottom and areas of vegetation were recorded on the large scale map. Three 1-hour gill net sets were made and a number of fish taken by anglers were secured for scale samples, weight-length data, and stomach analysis. The tributary streams were also examined in order to determine their relation to the lake's productivity. A record of the planting and fishing history is being compiled by a member of the State Department. When the study of the data is complete, a joint paper will be prepared covering this investigation. It is believed that valuable information will result from this study.

Strawberry Reservoir.—A marked decline in the fishing in this lake resulted in the request for a study to determine the cause and possible remedies. This investigation was begun in May, just before the break-up of the ice. At that time it was impossible to study conditions except at one point. Samples of the bottom water indicated a marked deficiency in oxygen which, if typical of the lake, might account for reported winter losses. Plans are made to obtain sufficient samples in February 1935 to determine the severity and extent of this deficiency.

Sets with the graded size gill net, the approximate efficiency of which has been determined, indicated an extreme scarcity of trout in June of this year. This, together with the small run of spawning fish, led to an order by the State Fish and Game Commission closing the reservoir and its tributaries to fishing in order to conserve the remaining stock of native cutthroat trout.

Samples of the plankton and bottom organisms in June and in August indicated a great abundance of both of these foods but a scarcity of shore forms, the latter being caused by severe fluctuation in water level. Stomach examination of trout and chubs (Tigoma) showed them to be direct competitors. The studies of June and August showed an abundance of oxygen to be present everywhere in the bottom waters. Apparently no summer deficiency occurs here, probably because of shallow water, exposed location and frequent heavy winds. Temperatures were found to be suitable everywhere, probably caused by high altitude and cold nights. Since all other conditions appear to be favorable, the explanation may be found in winter oxygen deficiency.

Scofield Reservoir.—Reports of poor catches at this lake, together with rumors of heavy winter losses, resulted in a request by the department for this study. Sets with the graded size gill net indicated a reasonable abundance of trout in a portion of the reservoir and thereby reassured guides and fishermen in that locality. Subsequent improvement in the catches confirmed our findings. Food samples showed a fair amount of plankton and bottom forms. Oxygen determinations during August at 6 scattered stations indicated a marked deficiency over about half of the area in spite of the fact that a maximum depth of only 21 feet was found. This indicates that there may be a decided winter deficiency which would cause a considerable loss of trout. Recommendations that heavy plantings here be avoided and that a study of winter oxygen conditions be made are being followed.

Bear Lake.—At the request of the Bureau's Division of Fish Culture, a study of Bear Lake, Utah-Idaho, was made possible by the defrayment of expenses by that division.

Chemical analyses made during a former study by the Bureau, and confirmed in part by this investigation, show an abundance of oxygen at all depths. The water is highly alkaline and, according to previous studies, contains considerable zinc. Temperatures were found to be entirely suitable for trout. A study of the food supply, however, indicated a decided deficiency. Plankton was found to be scarce. The Bureau's earlier workers also remarked the scarcity of phytoplankton and suggested that the high zinc content might be a cause. Bottom samples were poor in both the deeps and the shallows, the sand beaches being almost devoid of life. Limited areas of gravel and rocky shore supported a goodly number of organisms, including shrimp. Aquatic vegetation appeared to be limited to a few small patches of Potamogeton. Permanent lowering of the lake level by power development has resulted in a littoral zone composed almost entirely of sand, leaving stranded the original gravel and cobble beaches. This has undoubtedly eliminated a rich productive area and thereby decreased the lake's food supply. Sets with the graded size gill net indicated a scarcity of fish.

Observations following several plantings of fingerling trout and salmon indicated that heavy losses may be sustained due to the depredations of gulls, chub (Tigoma), and adult trout. A period of approximately 48 hours seems necessary for young trout and salmon to lose their conspicuous dark color and to acquire the strength and agility necessary to escape their enemies. Experiments in adaptation will be conducted by the Division of Fish Culture at this lake during the coming season in an attempt to overcome this loss in planting.

MUSSEL INVESTIGATIONS AND POLLUTION STUDIES IN INTERIOR WATERS

The various activities carried on by the staff under the direction of Dr. M. M. Ellis with headquarters and laboratories furnished by the

University of Missouri have been grouped under the two headings, mussel investigations and pollution studies. Attempts at artificial propagation of mussels have led to a study of the effects upon aquatic life of stream pollution by industrial wastes although these effects are by no means confined to mussels but extend to the food and game fishes as well.

FRESH-WATER MUSSEL INVESTIGATIONS

Mussel propagation experiments.—The raising of large numbers of fresh-water mussels in limited areas and with a limited water supply, which is being done successfully in the Fort Worth raceway experiments, presents a series of problems concerning which little or no data exist. Hence, a program of investigations was undertaken over a year ago looking ultimately to the solution of the practical problems of mussel farming. During the past year much progress has been made in this work. To date the findings may be summarized as follows:

Physical and chemical environment data.—A very complete set of data on the chemical and physical features of the environment suitable for the growth of fresh-water mussels has been obtained, including continuous daily records of temperature, dissolved gases, relative acidity, lime content, and other factors, for a period of over 14 months. These data have demonstrated that the calcium content of the water can be controlled and a calcium level suitable for proper shell growth readily maintained by the simple expedient of splashing the intake water through piles of limestone rubble, as was done in these experiments. From these records and analyses a set of normals has been established against which conditions in other experiments or even in other localities can be checked.

Bottom survival.—Commercially it is desirable that as large if not larger mussel populations be maintained on a given area of bottom in artificial raceways as would be found in natural waters. However, in the raceway the volume of water available is much less than in a natural river or stream. To determine, therefore, the balance between numbers of mussels per unit of bottom and amount of water flow, experiments on this phase of the raceway problems were undertaken. These experiments have yielded very definite results and have made progress to the next development possible.

The maintenance of proper bottom conditions for mussels in artificial raceways requires the constant flow of a large volume of water, so directed that the current will scour the bottom free of silt deposits.

Deposition of even so small a layer of silt as one-quarter of an inch in thickness, over the bottom of the raceway soon killed out even the adults of most species of fresh-water mussels. The harmful effects of erosion silt were greatly increased by particles of decomposing algae and other organic matter which in the undisturbed silt deposits, created a high oxygen demand. These findings on erosion silt and organic wastes confirm our previous statements, based on field work in natural waters, concerning the elimination of mussel beds in natural streams by silt deposits.

The volume of water required for the power scouring of raceway bottoms would be too large and too expensive to be practical under most conditions of mussel farming, if large numbers of mussels are to be handled in small areas and all of the available space utilized.

In the bottom survival experiments the yellow sandshell was found to be the least resistant to silting in, and the river mucket from Indiana, the most resistant, of the better commercial species. The best survival (considering the heavy-shelled species) against the unfavorable conditions brought about by silt deposit was made by the maple-leaf shell.

Mussel crate experiments.—From the results of the bottom survival experiments it was evident that in view of the average volume of water available for such raceways, it was not feasible to raise mussels in large enough numbers on the bottom to make the project commercially practical, especially with the silt hazard always an uncertain variable. With a view to eliminating the bottom silt hazard and also to increasing the actual number of mussels held in any raceway to a commercially desirable figure, crates in which mussels are now being raised, were devised for the raceways In these crates the mussels are relatively free from any sort of mud or silt hazard and as the trays of the crates are in tiers, from 3 to 10 times as many mussels are now being carried in a single crate as could be raised in the same bottom space as that supporting the crate. This advantage is gained too without any increase in the amount of water used. During 4 months of trial, the crates, of which we now have 3 types, are proving very successful, and the survival of the mussels in the crates has been excellent even though the animals are being crowded intentionally to determine the maximum number a given volume of water will support, both with and without artificial feeding. The effects of light penetration through the water on the animals in the top trays, the spread of mites, and the growth of algae on the trays are being followed simultaneously with the main experiment, and at present over 10,000 mussels are being carried in one series of crates alone in species survival, breeding stock, and age-class tests.

Physiological and biochemical studies of mussels.—In order to determine the success of various tests in the Fort Worth raceway project, as well as the condition of the mussels themselves, several lines of physiological and biochemical studies on mussels have been followed of necessity at the Columbia laboratories.

Food and food storage.—The feeding experiments have been continued at Columbia. The ability of mussels to utilize various types of cheap material as food was determined by biochemical analyses of the stored food. The relation of this stored food to survival and to the body condition of the mussel has just been checked in a series of experiments running over some 18 months. It was found that the yellow sandshell could survive complete starvation for 10 to 18 months before the reserve food supply was seriously depleted, if the animal were well fed to start with. The mussel seems to be an irregular feeder, storing large quantities of reserve food when food is abundant and easily available.

Reproduction.—So little is known concerning the breeding habits of most of the species of fresh-water mussels that various difficulties have been encountered in obtaining breeding stock for propagation and in selecting lines from which to raise mussels. Both at Columbia and Fort Worth test series are being held for reproduction studies, and attention is given to this phase of the work in the field.

The spawning habits of the Arkansas fanshell have been definitely determined and confirmed by observations in three different years by Thomas K. Chamberlain. In the field studies the formation of winter colonies has been discovered and significant observations on the method of fertilization obtained. Over 400 marked individual mussels have been collected from such colonies for study.

Internal and external activities as indices of condition.—The studies at Columbia of the mussel heart by H. L. Motley have provided normals with which the condition of mussels in the various experiments is readily compared. This heart test has also proved very helpful in field examinations as well as in the laboratory studies, and new information concerning the successful shipment of mussels has been one of the advances made through the application of these heart data. By slowing the heart action with cold, dry air (5°–10° C.) it was found that the metabolism of the animals could be reduced to almost the hibernation level. Applying this fact, living mussels have been kept out of water in dry air for over 80 days, and have remained in good condition throughout the tests, thus indicating a new safe method for the shipment of mussels over long distances and with no care on the part of the carrier. The survival in shipment tests has been practically 100 percent.

The observations on mussel activities under normal and adverse conditions have been greatly extended and are now being revised for publication.

POLLUTION STUDIES

Erosion silt.—The review of the mass data on erosion silt and its bearing on fisheries problems has been completed and the scientific results organized for publication. Particular attention has been given to the effects of erosion silt on light transmission, conductivity, water temperature, and salt content, as bearing on fisheries problems.

Arsenic investigations near Gardiner, Mont.—The study of arsenic pollution in Bear Creek, a tributary of the Yellowstone River near Gardiner, Mont., was made with reference to stream pollution and to possible storage of arsenic by certain aquatic insects which are eaten by the trout and whitefish. These investigations were particularly important to the program of pollution in that they pointed to an unlooked for source of storage which must be considered in future studies of other heavy metals as well as arsenic.

Cooperative projects with United States engineers.—The cooperative work with the United States engineers has been continued during the year. Plans are now being made for a continuation of these projects as requested by the office of the Chief of Engineers. This work consists in the investigation of stream conditions with reference to erosion and pollution and supplies much information on our inland waters.

New method for studying pollution effects.—As a result of difficulties encountered in previous studies of pollution problems and in view of the various discrepancies between existing observations on pollution and relative toxicity of pollution agents, experiments have been in progress for some time looking to the development of more satisfactory methods of study and to the standardization of results. New apparatus has been devised and new technique perfected which will be used in further pollution studies. These new methods involve the use of standard strains of plankton animals raised under controlled environments and tested under uniform conditions of temperature, light, etc., which can be repeated time after time with extreme accuracy. Both immediate and cumulative effects can be studied by this method. The findings in the plankton tests are verified on standardized fish preparations and on standardized free living fish, both in the laboratory and under controlled conditions out of doors. The new plan offers scientific data on pollution and pollution problems which were not obtainable by the other methods of study. Already the method has been applied to the investigation of heavy metal pollution, industrial wastes, and municipal wastes with excellent results in each case. A general standardization of pollution measurements is to be produced as rapidly as the work will permit.

In connection with the development of standard procedure for the maintenance of standard strains of plankton, the work required the reinvestigation of basic food for plankton, and it was found that this could be derived from several elements of waste now lost in general sewage disposal. Investigations of these various food constituents are now under way and one new combination for plankton food is in press from this work.

INDEPENDENT ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORIES

The Bureau owns and operates four Fisheries biological laboratories located respectively at Woods Hole, Mass.; Beaufort, N.C.; Fairport, Iowa; and Seattle, Wash.

The Woods Hole laboratory, provided with running salt water, a reference library, and the usual biological, chemical, and photographic laboratories and stock rooms, normally offers alcoves or tables for the free use of independent investigators engaged in research in marine biology. A marine fish hatchery is operated in conjunction during the winter, and a small public aquarium is maintained during the summer season. A 40-foot diesel-powered vessel, equipped for trawling, tow net, and hydrographic work, and smaller launches and rowboats are attached to the station.

The Beaufort (N.C.) laboratory has no public aquarium nor as extensive a library as at the Woods Hole station, but has running salt water and similar laboratory facilities and floating equipment. Owing to the mild climate and the terrapin hatching activities, the station is operated the year around and offers research facilities to private investigators.

Research activities at the Fairport (Iowa) laboratory, equipped for the investigation of fresh-water biology, have been entirely discontinued, owing chiefly to a lack of sufficient funds. The station is operated for the present by the Division of Fish Culture solely for the culture of warm-water pond fishes.

The Bureau's newest laboratory at Seattle, Wash., serves as headquarters for the Division's Pacific coast and Alaska research staff, whose activities are reported elsewhere, for the technologists and statistical agents of the Division of Fishery Industries, and for the staff of the International Fisheries Commission, United States and Canada. Although, except for a chemical laboratory, the building is not equipped for experimental biological research, complete plumbing was installed in most of the rooms when the building was constructed so that it can be adapted readily for experimentation in the future should fishery investigations in that region develop so as to require such equipment. Hence no facilities are available for guest investigators.

WOODS HOLE LABORATORY

During the summer of 1933 experiments on the physiology of the oyster were continued by Dr. P. S. Galtsoff and R. O. Smith and experiments on methods of marking mackerel were carried on by O. E. Sette at the Woods Hole Biological Station. Continued lack of necessary operating funds prevented other work at this station.

This is the second summer that this well-equipped marine laboratory, capable of providing facilities for some 20 investigators, has been largely unused. In the meantime, problems of importance to the development of fisheries biology, whose solution would greatly facilitate progress in the major investigations on the condition of our fisheries, are rapidly accumulating. Among these are: (1) The effect of temperature and food on the rate of growth of certain food fishes; (2) the effect of group behavior on activity and rate of growth; (3) the physiological effects on the fish of injuries received in tagging operations; (4) the effect of temperature on calcium metabolism and consequent alteration of scale structure; (5) the factors responsible for high mortality in the larval stages of fishes; (6) the effects of temperature on the respiratory mechanism of mackerel. These and many other problems might readily be attacked at very little expense to the Government by volunteer investigators from universities if they could be provided the facilities. Hence resumption of normal activities at the Woods Hole laboratory is urgent.

BEAUFORT LABORATORY

Research.—Operation of the Beaufort laboratory was continued throughout the year under the direction of Dr. H. F. Prytherch and furnished facilities for the study of fishery problems of the South Atlantic and Gulf region. The chief investigations conducted here at present by the Bureau's staff are reported elsewhere. Laboratory facilities for marine research have been furnished to 13 independent research workers from other institutions who have engaged for short periods of time in the following studies: Dr. H. V. Wilson, University of North Carolina, behavior of living cells of Polyzoa; Irene Bolick, University of North Carolina, lymph cells of Echinoderms; W. H. Hadley, Jr., Cornell University, the foraminifera of the North Carolina coast; H. C. Burdick, State University of Iowa, metabolism of fish; Dr. Bert Cunningham, Duke University, relation of temperature to rate of development of terrapin embryos; Dr. P. B. Powers, University of Pennsylvania, ciliate Protozoa of Echinoderms; F. R. Brown, Vanderbilt Medical School, spermatozoa of Prosobranch snails; L. Lyndon Williams, Rensselaer Polytechnic Institute, distribution of marine invertebrates in the vicinity of Beaufort; Dr. Hoyt S. Hopkins, New York University, respiration and tissue-glycolysis in bivalve mollusks; Earl Mathis, Northwestern

University, susceptibility of fish to tubercular bacilli; Dr. Duncan S. Johnson, Johns Hopkins University, the ecology of vegetation of Bogue and Shackleford Banks; Donald B. Lawrence, Johns Hopkins University, effect of sand dunes movements on flora of Shackleford Banks; Edward D. DeLancaster, Johns Hopkins University, blue-green algae of the Beaufort region.

The facilities of the station were also utilized by the United States Chemical Warfare Service for tests of wood preservatives and by the Bureau's Division of Fishery Industries for experiments on the durability of net twines treated with different preservatives. Cooperative tests were made with the Woolsey Paint Co. in respect to the antifouling and protective value of copper paints; with the Tropical Paint & Oil Co. on the suitability of Bakelite varnish for marine use; and with the Union Carbide & Carbon Corporation to determine the value of different grades of stainless steel and other steel alloys for the prevention of fouling of ship bottoms.

Terrapin culture.—The propagation of diamond-back terrapin was continued at the Beaufort laboratory in cooperation with the Division of Fish Culture and yielded in 1933 a total production of 10,060 young terrapins, which is next to the highest record obtained thus far in the culture of this species. For the first time the distribution of young terrapins has been extended so as to include the waters of Florida, South Carolina, and North Carolina.

In cooperation with the Florida Department of Conservation 2,000 terrapins were planted on May 12, in selected marshes and protected areas in the Choctawhatchee Bay region. In South Carolina a similar planting was made on April 27, in the vicinity of Charleston in cooperation with the State Board of Fisheries. A somewhat greater distribution of young terrapins amounting to 5,730 was made in North Carolina in cooperation with the Department of Conservation, because of the scarcity of terrapins in these waters and in appreciation of the continued support received from this State in propagation of this species. The remaining 330 terrapins have been saved for breeding purposes and for the continuation of the experimental studies conducted by Dr. George T. Hargitt and Dr. Bert Cunningham, of Duke University.

Over 93½ percent of the original hatch of 10,574 were successfully reared to the age of 9 months at the Beaufort laboratory before liberation. It is believed that these operations establish the highest survival record yet obtained in the culture of fresh water and marine animals where the young of a species are reared over a period of several months. The output of the Beaufort station hatchery since 1930 has been as follows: 1930, 5,778; 1931, 5,500; 1932, 11,086; and 1933, 10,060. During the summer of 1933 a new brood of 10,624 young terrapins was obtained. These terrapins are now being fed for a short period in the fall and are then placed out of doors in protected hibernating pens in order to reduce the cost and labor of their care and feeding as required previously when they were kept during the winter in the heated rearing house. Distribution of the 1933 brood will be made during the following spring throughout the South Atlantic States in cooperation with the various State departments.

APPROPRIATIONS

The work of the Division of Scientific Inquiry during 1933 was supported chiefly by the appropriation "Inquiry respecting food fishes", of which approximately one-half was available from the last half of the fiscal year ending June 30, 1933, and half from the appropriation ending June 30, 1934. The amount appropriated under this heading for the fiscal year 1933 amounted to $200,000, but owing to administrative deductions under the Economy Act and by official order the amount available for expenditure was only $178,001. During the fiscal year 1934, $173,000 was appropriated under the same heading, but of this amount only $122,033 was available for expenditure. The appropriation for 1934 is therefore a reduction of 31.4 percent from the funds available for 1933, which in turn was a reduction of 31 percent from the amount appropriated in the previous year. A summary of the amounts available for the various major projects follows.

Projects	1933	1934
Commercial fishery investigations	$92, 711	$65, 855
Oyster cultural investigations	32, 552	22, 932
Aquicultural investigations	39, 538	30, 506
Conserving fish by screens and ladders	5, 491	250
Washington Laboratory and administration	7, 719	2, 500
Total	178, 001	122, 033
Allotment for maintenance and operation of vessels	14, 000	10, 000

This reduction in appropriation has resulted not only in the serious curtailment of field work in connection with all of the projects and legislative reductions in salary, as well as the assignment of administrative furlough to all the investigators, but has required the dismissal of a number of the Division's regular staff. The most serious aspect of this reduction in personnel lies in the diversion of skill, experience, and technical training from fishery research into other fields rather than in the increase of unemployment thereby. This is a loss which will have a lasting effect upon the development of fishery science and aquiculture for men with adequate fundamental training and sufficient practical experience to conduct productive studies in these fields are extremely limited in number. Since few universities offer adequate training in these lines, the rebuilding of a scientific staff in the future will be correspondingly retarded.

Two of the Bureau's biological laboratories have been closed, and, as noted elsewhere, the vessel facilities have been severely curtailed by the loss of the *Albatross II*, which was laid up during the fiscal year 1932 and decommissioned on July 1 of that year, thus leaving the Bureau with no means whatever of conducting certain essential types of investigations on the fishing grounds where the most important marine fisheries of the United States are prosecuted.

With the complete expenditure of funds allotted by the Public Works Administration during the coming fiscal year, certain projects of great value to the fishery resources of the country that have gotten well under way will have to be abandoned for lack of regular appropriations for their continuation. One of these projects is the investigation of stream pollution and means of neutralizing or properly utilizing waste materials now rendering large portions of our streams unfit for aquatic life.

With the construction of dams on the Columbia River, the salmon runs of that watershed will be seriously menaced. Continued observations on the effectiveness of fish protective works at the Bonneville Dam will be required after the expenditure of the Public Works allotment, and these studies must be coordinated with similar studies at other dams now built or under construction. This work should be carried on for at least a 10-year period by regular annual appropriations.

With Public Works funds, a favorable beginning will have been made in planning a rational stocking policy for the waters of the public domain included in the national forests. Less than one-sixth of the total forest area can be covered, however, with the allotment during the coming year and, forming as it does the very foundation of fishery conservation in interior waters, should be continued on the present scale until the entire area of the national forests has been covered. This work likewise should be supported by annual appropriations commensurate with the importance of the undertaking.

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